PALEONTOLOGY JUL 27 1960 MUSEUMS LIBRARY

Volume 34 JULY, 1960 Number 4

JOURNAL OF PALEONTOLOGY

A publication of The Society of Economic Paleontologists and Mineralogists *and* The Paleontological Society *with the generous support and cooperation* of The American Association of Petroleum Geologists *and* The Geological Society of America

CONTENTS

Ammonoid classification problems ..... *V. E. Ruzhencev* 609
Devonian stromatoporoids from the lower Mackenzie Valley of Canada ..... *J. J. Galloway* 620
Permian fusulinids from Guatemala ..... *Stanley A. Kling* 637
The Pennsylvanian ostracode *Bairdia oklahomaensis* in Indiana ... *Robert H. Shaver* 656
The geologic significance of coiling ratios in the foraminifer *Globigerina pachyderma* (Ehrenberg) ..... *Orville L. Bandy* 671
Triassic ammonoids from Thailand ..... *Bernhard Kummel* 682
Osgood (Niagaran) bryozoans from the type area ..... *T. G. Perry* and *Donald E. Hattin* 695
Fauna from the Tensleep sandstone in Wyoming ..... *R. D. Hoare* and *J. D. Burgess* 711
Population study of charophyte species, Morrison formation, Colorado ..... *Charles A. Ross* 717
Ultrasonic vibrations as a cleaning agent for fossils ..... *Calvin H. Stevens, Daniel H. Jones,* and *Robert G. Todd* 727
Carboniferous goniatites from Caballeros Canyon, State of Tamaulipas, Mexico ..... *Grover E. Murray, W. M. Furnish,* and *José Carrillo B.* 731
Magnetic separation of conodonts ..... *Verne E. Dow* 738
Magnesium, strontium, and aragonite in the shells of certain littoral gastropods ..... *David Krinsley* 744

PALEONTOLOGICAL NOTES

Photography of Paleozoic arenaceous Foraminifera ..... *R. C. Gutschick* 756
Stratigraphy and paleontology of an occurrence of diatomaceous earth in Nebraska ..... *John D. Bates* and *George Biemesderfer* 759
Chaetetes in the Bird Spring Formation near Lee Canyon, Clark County, Nevada ..... *Mark Rich* 761
Occurrence of vertebrate remains in Nebraskan till of north-central Missouri ..... *Lloyd J. Schmaltz* 762
Authorship of name *Mesolobus striatus* ..... *J. Marvin Weller* 762

SOCIETY RECORDS AND ACTIVITIES

Reports and minutes of the thirty-fourth annual meeting of the S.E.P.M. 763
Revised Constitution and By-Laws 781
S.E.P.M. nominees for office, 1961-1962 786
New officers, Permian Basin Section, S.E.P.M. 791

EDITORS

For The Paleontological Society: ROBERT V. KESLING, Museum of Paleontology, University of Michigan, Ann Arbor, Michigan.

For The Society of Economic Paleontologists and Mineralogists: M. L. THOMPSON and CHARLES COLLINSON, Illinois State Geological Survey, Urbana, Illinois. Associate Editors: Robert H. Shaver, Indiana Geological Survey, and Alan B. Shaw, Shell Oil Company.

The JOURNAL OF PALEONTOLOGY is published bimonthly. The issues for January, May, and September are sponsored by The Paleontological Society in cooperation with The Geological Society of America; those for March, July, and November are sponsored by The Society of Economic Paleontologists and Mineralogists in cooperation with The American Association of Petroleum Geologists.

The subscription price for the JOURNAL is $15.00 per year prepaid to addresses in the United States. Postage is charged extra for all other countries in the Postal Union, 40 cents on annual subscriptions (total $15.40). Single numbers $3.00 each to nonmembers, $1.75 to members.

Communications about the JOURNAL, advertising, subscriptions, rates, change of address, and nonreceipt of preceding numbers, should be addressed to The Society of Economic Paleontologists and Mineralogists, P. O. Box 979, Tulsa 1, Oklahoma. Claims for nonreceipt of preceding numbers must be submitted within three months of the date of publication in order to be filled gratis. Communications about membership and requests for blanks for nomination of new members should be directed to the secretary of the respective society.

Authors should consult a recent issue of the JOURNAL for appropriate style and form before preparing their manuscripts. A brief informative abstract should accompany every article, except paleontological notes, nomenclatural notes, or short papers in which the title is sufficient to serve as an abstract of the contents. All new taxonomic names proposed in a paper should appear in the abstract.

Contributors are requested to instruct their photographers to illuminate fossils from the upper left side, the conventional manner. Plates normally should be arranged for publication at the maximum size of 5½×8½ inches, exclusive of margins and heading. Text-figures should be designed for reproduction at either single column (2½ inches) or full page (5½ inches) width, maximum height 7½ inches. Typewritten copy is not acceptable for text-figures.

OFFICERS OF THE SOCIETIES

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

For the year ending April 1961

President
WILLIAM M. FURNISH, Iowa City, Iowa

Past-President
SAMUEL P. ELLISON, Austin, Texas

Vice-President
LAURENCE L. SLOSS, Evanston, Illinois

Secretary-Treasurer
JOHN IMBRIE, New York City

Editors
M. L. THOMPSON AND CHARLES COLLINSON
Urbana, Illinois
for Paleontology

JACK L. HOUGH, Urbana, Illinois
for Mineralogy

THE PALEONTOLOGICAL SOCIETY

For the year ending November 1960

President
KENNETH E. CASTER, Cincinnati, Ohio

Vice-President
JOHN W. WELLS, Ithaca, N. Y.

Secretary
HARRY B. WHITTINGTON, Cambridge, Mass.

Treasurer
CLAUDE C. ALBRITTON, Dallas, Texas

Editors
ROBERT V. KESLING, Ann Arbor, Mich.
ERWIN C. STUMM, Ann Arbor, Mich.

Past-Presidents
ARTHUR K. MILLER, Iowa City, Iowa
G. ARTHUR COOPER, Washington, D. C.
HENRYK B. STENZEL, Houston, Texas

Second-class postage paid at the Post Office at TULSA, OKLAHOMA, and an additional mailing office, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in paragraph 4, section 538, P. L. and R, authorized April 3, 1935.

Printed in U. S. A.

GEORGE BANTA COMPANY, INC., MENASHA, WISCONSIN

JOURNAL OF PALEONTOLOGY

A publication of THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS *and* THE PALEONTOLOGICAL SOCIETY *with the generous support and cooperation of* THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS *and* THE GEOLOGICAL SOCIETY OF AMERICA

VOLUME 34 JULY, 1960 NUMBER 4

AMMONOID CLASSIFICATION PROBLEMS

V. E. RUZHENCEV
Paleontological Institute, Academy of Sciences of the USSR, Moscow

ABSTRACT—A genetic terminology of the ammonoid suture line is defined and some doubtful aspects of this general problem are considered. Study of ontogenetic sutural development is shown to be most significant in ammonoid classification. Five orders of Ammonoidea (Agoniatitida, Goniatitida, Clymeniida, Ceratitida, and Ammonitida) are recognized and defined.

INTRODUCTION

A SYSTEM for the organic world must be the phylogenetic one. In elaborating such a system, one should take into account all the peculiarities of organization in the development of components, making a distinction of the essential characters for each stage of evolution (the principle of the main phylogenetic link). The moment of establishment of a new peculiarity should attract special attention. At the beginning of the history of a group, the main link in the chain of characters does not coincide, as a rule, with the more striking peculiarity because the influence of older characters is still great. Therefore, it is important not to be mistaken in the definition of a nodal point, where for the first time traces of a new organization arise in the midst of the old system, these relatively obscure traces point out the beginnings of new taxonomic groups of various ranks.

Ontogenetic researches have been, and always will be, a reliable basis for classification. However, the success of such a work depends on the coordinated study of ontogenesis and phylogenesis, *i.e.*, on the study of evolution of ontogenesis itself. All stages of individual development should be investigated, but the exact significance for determination of taxonomic questions must be analyzed carefully. Early stages define the phylogenetic kinship of larger groups and even serve as a foundation for ascertainment of higher taxa, such as orders or suborders. Later stages point to concrete ancestral genera or species.

The suture line is of the greatest significance for classification of Paleozoic and Mesozoic ammonoids. Its features must be a necessary part in any true diagnosis of a species or genus. The particular pattern of ontogenetic development in suture lines is the most reliable single family character. On the same basis, higher taxa can be distinguished as well. In establishing the interrelationships of different groups one should never foreget the two most important principles of paleontological investigations, those of the main phylogenetic link and the ontogenetic pattern.

A GENETIC TERMINOLOGY OF SUTURE LINE ELEMENTS

The first attempts to establish sutural terminology may be found in the papers by F. Noetling (1905, 1906), R. Wedekind (1913a,b, 1914, 1916a,b, 1918) and C. Diener (1916a,b). Their investigations were carried still further by H. Schmidt (1921, 1925, 1934, 1952) and, especially, by O. Schindewolf (1928, 1929, 1933, 1951, 1953, 1954a,b, 1957), who accumulated valuable data on the ontogenetic development of the suture line and came to some interesting conclusions concerning phylogeny of Paleozoic ammonoids. It must be noted, however, that there was a disagreement between Schindewolf and Schmidt on many points, and they often gave different formulae, even in comparatively primitive genera. These controversies were caused by a different scope of available material, by subjective understanding of the process of development, and by use of different symbols. Hence, it is clear that the method propounded by Noetling has not been carried out satisfactorily in German paleontology, in spite of the great efforts that have been made by very experienced paleontologists. In other countries this problem seems to have received practically no attention at all, although it is one of primary importance.

The method of composing genetic formulae proposed by myself (Ruzhencev, 1949a,b) is based on the following two requirements:

1. Symbols must reflect exactly the primary position of any lobe, in spite of all onto-phylogenetic changes it may undergo afterwards. That is, its position at the moment of origin is most important.
2. Formulae must reflect exactly the whole course of ontogenetic development in any suture line, however complicated it may be.

In order to meet these requirements, the following designations are introduced:

MAJOR ELEMENTS

V—*Ventral lobe* is situated on the venter, on both sides of the median line. This lobe is, indeed, a primary one, for it existed in bactritoids which gave rise to ammonoids. This is, therefore, the oldest lobe or the *first element* of the suture line. With the same symbol we designate elements resulting from the subdivision of the primary ventral lobe, and also those derived from the secondary ventral saddles. German paleontologists designate this lobe with the letter *E* to indicate its external position, but as there are many external lobes, the symbol *V* seems to define the nature of this element more exactly.

O—*Omnilateral lobe* is proposed to designate an extremely wide lobe originally occupying all the space between the narrow external saddle and dorsal or, in other cases, internal saddle. This is the *second element* of the suture line known already in bactritoids, *Lobobactrites*, and is characteristic of a definite stage of evolution in the oldest ammonoids. In later forms it was replaced by other elements.

D—*Dorsal lobe* is situated on the dorsum, having arisen in place of the primary dorsal saddle. This is the *third element* of the suture line. The same symbol is used for elements resulting from the subdivision of the primary dorsal lobe or derived from the secondary dorsal saddle. German paleontologists use the letter *I* for this lobe to indicate its internal position, but there are other internal lobes, and our designation seems to express the essence of this element more exactly.

U—*Umbilical lobe* originates on the external side of the shell near the umbilical seam and divides the primary external and internal saddle. The umbilical lobe substitutes for the more primitive omnilateral one. Throughout ontogenetic development, it remains either in the original position or shifts to the flanks and becomes a *morphological* lateral lobe. This shift does not mean that the symbol should be changed, for our terminology is based upon the primary position of lobes. This is the *fourth element* of the suture line. With the same symbol *U* we designate elements originating by the subdivision of the primary umbilical lobe; also those arising independently from the apex of the saddles between the elements *U* and *I* in some groups of ammonoids and between the elements *L* and *I* in others. Noetling, and later Wedekind and Schindewolf, called this lobe a lateral one and designated it

with the letter *L* in spite of its original umbilical position. Schmidt used a variety of letters for this lobe: *L*, *U*, and others (see Schindewolf, 1954b, p. 139).

I—*Internal lateral lobe* is derived from the apex of the saddle separating the lobes *D* and *U*. Originally this lobe is crossed by the umbilical seam, *i.e.*, it is situated partly on the external and partly on the internal surface of the shell; but later it passes completely to the internal surface where it remains constantly in a majority of ammonoids. However, in some groups this lobe *I* shifts again to the external surface. This is the *fifth element* of the suture line. The same symbol is applicable to elements arising by the subdivision of the primary internal lateral lobe and also to those appearing independently in the apex of the saddles separating the elements *I* and *D*. German paleontologists designate this lobe with the symbol U_1 (umbilical) or *K* (Kehllobus). These symbols are not suitable, for the first of them has been used for the primary umbilical lobe which appears earlier in phylogenesis, and the second one tells nothing about the true nature of this element. A descriptive designation of this lobe must be connected to its origin from the apex of the primary *internal* saddle.

L—*External lateral lobe* appears primarily as a lateral projection of the ventral lobe and then shifts to the apex of the external saddle in the course of ontogenetic development. Still later in phylogenesis, because of acceleration in development, this element originates directly in the apex of the external saddle. Morphologically it is always an external lateral lobe. This is the *sixth* and the *last primary element* of the suture line. The same symbol is used for elements originating by the subdivision of the primary external lateral lobe and also for those appearing independently in the apex of the saddles separating the elements *V* and *L*. Wedekind, and subsequently Schindewolf, called this lobe an adventive one and designated it with the symbol A_1. Such a symbol is not suitable, for in the old purely morphological terminology all the secondary lobes connected with the first lateral saddle were called adventive. Some authors extended this term also to other additional elements of the suture line appearing in the second saddle, the third one, and so on. In our genetic terminology, the designation of this lobe indicates its origin in the zone of the primary *external* saddle.

ADDITIONAL ELEMENTS

The six lobes discussed above are the basic elements inherent in primitive groups of ammonoids. For composing genetic formulae of the more complicated forms, additional symbols are needed which reflect two processes: the subdivision of the primary lobes and the appearance of new lobes in the apex of the saddles. The system proposed gives numbered symbols for representation of all the subsequent lobes.

L_1, $U_{2\cdot1}$, $I_{2\cdot1\cdot1}$—*Lowered or subscript figures* indicate that new elements appeared as a result of subdivision of the primary lobes. The number of figures shows how many times this subdivision took place. Lobes appearing by the first subdivision have one figure (L_1 or L_2), lobes originating by the second subdivision of the same primary lobe have two figures ($L_{1\cdot1}$ or $L_{2\cdot1}$). and so on. The numerals themselves show the order of origin of secondary lobes.

( )—*Brackets* enclose those lobes that are not isolated completely one from another, *i.e.*, the saddles separating them are lower than the neighboring ones.

L^1, U^1, U^2—*Raised or superscript figures* indicate the order of independent secondary appearance of new lobes in the apex of saddles. The primary lobes *V*, *O*, *D*, *U*, *I*, *L* have no such numbered symbols.

:—*Colon* indicates the position of umbilical seam, *i.e.*, the line of junction of the external and internal walls of the shell.

Example 1: **Timanites**—$(V_2V_1V_2)UU^1U^2{:}ID$. The ventral lobe has undergone an incomplete subdivision into three parts. Between the primary umbilical and internal lateral lobes two extra umbilical lobes independently arose.

Example 2: **Agathiceras**—$(V_1V_1)L_2L_1L_2U{:}ID$. The ventral lobe became symmetrically divided into two parts. The external lateral lobe disintegrated into three independent elements.

Example 3: **Schistoceras**—$(V_1V_1)LU_1{-}U_{2\cdot2}U_{2\cdot1}{:}U_{2\cdot2}ID$. The ventral lobe as above. The umbilical lobe evolved into two elements, the inner one being retarded. There-

upon the latter subdivided into three independent lobes, two of which remained on the outer side and one passed onto the inner side of the shell.

Example 4: **Popanoceras**—$(V_1V_1)L_2L_1L_{2\cdot1}$ $(L_{2\cdot1\cdot1}L_{2\cdot1\cdot1})$ $U^1U_1{:}U^2U_2$ $(I_{2\cdot1\cdot1}I_{2\cdot1\cdot1})I_{2\cdot1}(I_{1\cdot1}$-$I_{1\cdot2})(D_2D_1D_2)$. The ventral lobe as above. The external lateral lobe gave rise to four independent elements: at first it distintegrated into three independent lobes; then the third of them in turn developed into two lobes, the second one of these then became wide and bifid. The primary umbilical lobe evolved into two independent elements, and subsequently two more umbilical lobes arose in the apex of saddles. The internal lateral lobe gave rise to three independent elements: at first it disintegrated into two parts one, nearest the seam, being retarded; then the part adjacent to the dorsum evolved into two connected lobes, and the second part developed into two independent lobes, that nearest the seam becoming wide and bifid.

As the examples show, the formulae of the suture lines are based only on the lobes. The saddles, therefore, have no special symbols. In cases where reference to some definite saddle is needed, it can be designated with a fraction composed of the symbols of adjacent lobes. Consequently, the first external saddle separating the ventral and umbilical lobes will be designated V/U.

The new terminology was put in practice by myself in a number of monographs (Ruzhencev, 1950, 1951, 1956), as well as by other Russian authors (Drużczic, 1956; Besnossow, 1958; Bogoslovsky, 1958); it contributed also to an elaboration of the phylogenetic system of the Paleozoic ammonoids (Ruzhencev, 1957).

VEXING PROBLEMS OF TERMINOLOGY

To introduce a new terminology instead of using the existing one is always a difficult task and serious responsibility. Nevertheless, I have decided to do it, keeping in mind that a single and universally adopted terminology of the suture line has not yet been elaborated. German paleontologists still debate this question, and paleontologists of other countries have not yet realized the importance of genetic formulae.

In the following list the main symbols used by Russian and German paleontologists are correlated:

Ruzhencev	V	L	U	I	D
Schindewolf	E	A_1	L	U_1	I
Schmidt	E	L	U	K	I

The principal confusion in terminology, leading to serious disagreement among the paleontologists, has arisen because some authors (Noetling, Wedekind, Schindewolf) have termed: the primary umbilical lobe a lateral, the primary external lateral lobe an adventive one, and the primary internal lateral lobe an umbilical one. These basic differences have been correctly represented in my papers (Ruzhencev, 1949a,b) by introducing symbols corresponding to the primary position of the lobes. Some symbols were borrowed from the works of Schmidt. Schindewolf (1951) then concluded that the new symbols did not take into account ontophylogenetic development of the suture line and that they were based on the normal position of lobes in Carboniferous and Permian ammonoids. It seems to me that this author has not manifested complete objectivity in this question, for the matter appears quite the opposite in the light of explanations of genetic meaning given above. Further, in discussing the real process of development of the suture line in different stages of ammonoid evolution, it will become even more obvious.

While considering Schindewolf's view concerning initial ontogenetic development of the suture, W. J. Arkell indicates, perhaps unintentionally, failure of the symbols proposed by the German author. Arkell says (1957, p. 102): "In the Prolecanitina *the lateral lobe* arises *near the umbilical seam* and in the course of development shifts ventrally until it occupies a normal position, midway between the umbilical seam and the mid-line of the venter, while at the same time *a new umbilical lobe* arises in the vicinity of the umbilical seam. This is the normal course of development for all Mesozoic ammonoids and indicates their ancestry in the Prolecanitina. In the Goniatitina, on the other hand, the lateral lobe remains small and *close to the umbilical seam throughout development*, while a false lateral lobe gradually forms in the middle of the lateral saddle" (italics by V.E.R.).

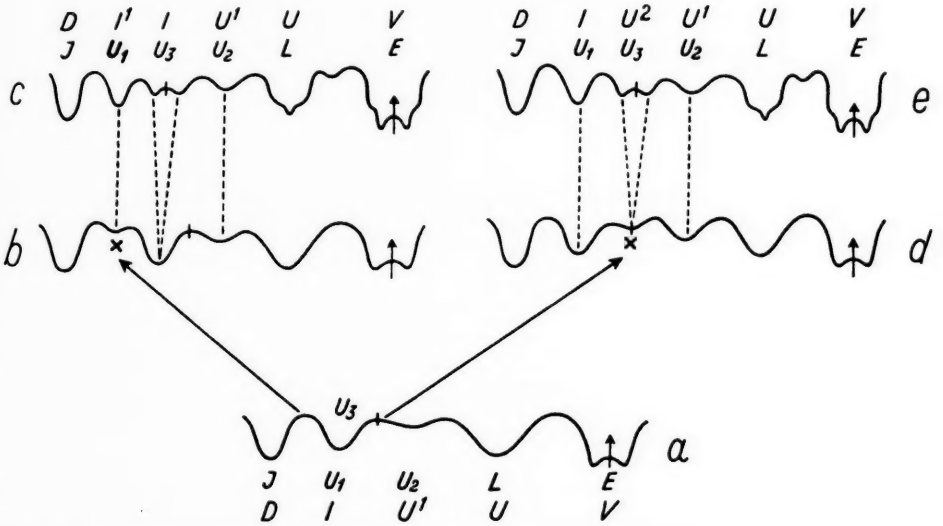
Arkell thus shows unconsciously that Schindewolf's lateral lobe (L) is in reality the umbilical lobe (U), because it arises near the umbilical seam. If it shifts ventrally, a *new* umbilical lobe arises in its place. With such wording, that author emphasizes that the *old* lobe was also umbilical. As to the real lateral lobe, which arises in the apex of the external lateral saddle, Arkell calls it a "false" lateral lobe. Everyone who reads his quotation critically will realize what confusion may be introduced by German terminology and symbols.

We can all come to the same conclusion if we analyze how Schindewolf himself uses these symbols in his paper on Jurassic ammonoids. Text-figure 1 reproduced from his paper (1953) illustrates the development of the suture line in representatives of the superfamilies Stephanoceratacеae and Perisphinctaceae. Without changing anything else, I have added other symbols for the lobes. In both these groups (Text-fig. 1a) the development of the suture line begins with the stage $(V_1V_1)UU^1{:}ID$, which is observed already in the second septum. In this initial stage, Schindewolf designates the same internal lateral lobe by two symbols, U_1 and U_3. Then in the Stephanoceratacеae (Text-fig. 1b,c), between the lobes I and D, a second internal lateral lobe I^1 arises. In the Perisphinctaceae (Text-fig. 1d,e), a third umbilical lobe U^2 appears between the lobes U^1 and I. As a result two basically different suture lines develop:

1. Stephanoceratacеae—$(V_1V_1)UU^1II^1D$
2. Perispinctaceae—$(V_1V_1)UU^1U^2ID$

However, Schindewolf utilizes but one formula, $ELU_2U_3U_1I$. In this case we have not only improper symbols, but a wrong interpretation of development. The lobes U_3U_1, which Schindewolf attributes to two stocks, are in reality quite different by origin in each group, as his own figures show. These lobes are not homologous, but only analogous lobes II^1 and U^2I. Hence, the nomenclature proposed by Schindewolf serves to obscure rather than to elucidate the question. This thought must be emphasized, for the genetic formulae of suture lines are of great importance in formulating a phylogenetic system for ammonoids.

While examining the symbols proposed by me, Schindewolf (1951) presents the following question: In a number of genera the umbilical lobe shifts to the middle of the flanks; does it become a lateral one or is such a lobe absent in these ammonoids? The answer is, many ammonoid genera have



TEXT-FIG. 1—Development of the suture line in representatives of the superfamilies Stephanoceratacеae (a,b,c) and Perisphinctaceae (a,d,e) (from Schindewolf, 1953, with new symbols added).

no genetic lateral lobe; this fact is of course greatly important in the classification of ammonoids.

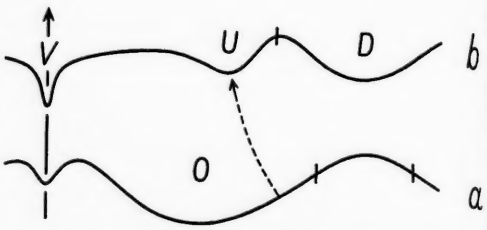
The lobes *V, U, D* (in German terminology *E, L, I*) are called *protolobes* by Schindewolf, in contrast with the subsequent ones which are termed *metalobes*. Such a subdivision is needless; for, as has already been stated, the lobes arose at different ontophylogenetic stages and are unequal in this respect. In addition, such a classification has no practical advantage. Therefore, one may agree with Schmidt (1952) who criticized the subdivision of the primary lobes into proto- and metalobes. It is needless to designate "metalobes" with numbered symbols (U_1 and A_1 according to Schindewolf) for it complicates the composition of formulae of highly organized ammonoids. Figures above or below (superscript and subscript) letters are necessary, however, for designation of the mode and the order of origin in new lobes. Consequently, only the six primary lobes in my system are designated with letters alone, without any figures.

EVOLUTION OF EARLY STAGES OF THE SUTURE AS A BASIS FOR AMMONOID CLASSIFICATION

The first septum and prosuture were formed in the egg capsule and are not suitable for deciphering an ammonoid classification system. The solution of this problem must be based upon the second and subsequent suture lines. It is interesting from this standpoint to trace the evolution of early sutural stages; these are of special importance in establishing higher taxonomic categories.

In the system proposed by myself (Ruzhencev, 1957) the Ammonoidea have been subdivided into five orders: Agoniatitida, Goniatitida, Clymeniida, Ceratitida and Ammonitida.

The ventral and omnilateral lobes were inherited by ammonoids from the ancestral group, bactritoids. The mature suture line in the oldest and most primitive representatives of the order Agoniatitida was composed only of these two lobes (Text-fig. 2a), the formula being *VO*. In the course of subsequent development of the order a dorsal lobe *D* appeared, and the formula became



TEXT-FIG. 2—The most primitive suture lines of agoniatites: a. *Gyroceratites gracilis* Bronn; b. *Anarcestes lateseptatus* (Beyr.); Middle Devonian (from Schindewolf, 1933, with our symbols).

VO:D. The formation of a wide omnilateral lobe occupying all the space between the venter and the umbilicus did not contribute to further complication of the septum. Therefore, among agoniatites another type of suture line arose (Text-fig. 2b) with the umbilical lobe *U* instead of the omnilateral one. Such a suture line, represented by the symbols *VU:D*, was *initial for all subsequent ammonoids.*

In the course of subsequent rapid evolution the internal lateral lobe evolved, some new umbilical lobes appeared, the ventral lobe became subdivided, and so on. All these changes, connected with the isolation of the three new orders (clymenias, ceratites, and ammonites), appeared at different stages of individual development. Thereupon, owing to ontogenetic acceleration, more or less complex suture lines encroached upon ontogenetic stages and were crowded back *to the second septum inclusive.* Thus different types of the second sutures arose. In Paleozoic ammonoids, with the exception of the oldest, they were composed of the ventral, umbilical, and dorsal lobes. In Triassic ceratites, the internal lateral lobe was added. In Jurassic ammonites, further complication proceeded; at first a second umbilical lobe arose, and then the ventral lobe became bifid. Cretaceous period ammonites appeared with a simpler second septum, a bifid ventral lobe, but only one umbilical lobe. Consequently, the evolution of the second suture line proceeds in the following direction:

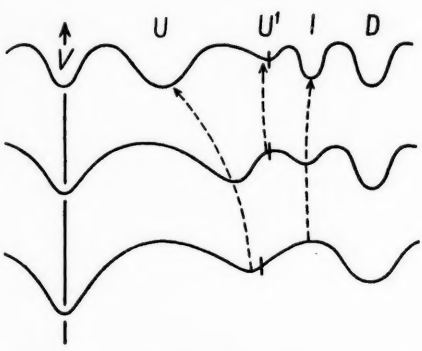
$$VU{:}D \rightarrow VU{:}ID \rightarrow VUU^1{:}ID \rightarrow (V_1V_1)UU^1{:}ID \rightarrow (V_1V_1)U{:}ID.$$

In groups developing in the direction of considerable simplification there were forms with the second suture corresponding to the

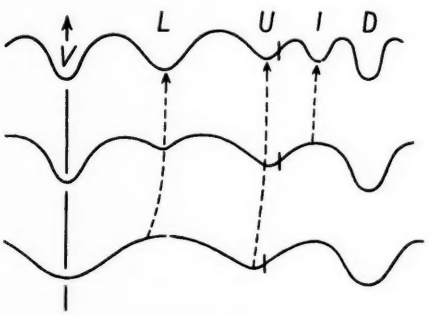
formula *VU* (e.g., *Indoceras*) signifying return to a form like that of early ancestors.

Evolution of the suture line in goniatites was of quite another type. In representatives of this group the second suture line consisted only of three lobes *VU:D*.

In elaborating a system for ammonoids not only the second suture line is of a great importance, but the subsequent ones as well. If we exclude the oldest and most primitive agoniatites, which were developing with the sutural type *VO*, all the remaining Paleozoic ammonoids will naturally split into two groups with radically different early ontogenesis. They are united, however, by the initial second suture line *VU:D*. In the first group (agoniatites), a septum was developed with the formula $VUU^1:ID$; among new lobes, first the internal lateral lobe (*I*) was added and then the second umbilical lobe (U^1) appeared. The primary umbilical lobe (*U*) shifted meanwhile from the umbilical zone to the flanks (Text-fig. 3). In the second group (goniatites), a septum was formed with the formula *VLU:ID*; among new lobes, first the external lateral lobe (*L*) and then the internal lateral lobe (*I*) evolved. The primary umbilical lobe (*U*) did not change its position near the seam (Text-fig. 4). In both these groups the number, form, and position of elements appear to be identical; nevertheless the origin of the whole suture line is radically different. The agoniatites were developing by the type *VU*, while the goniatites evolved by the type *VLU*. Only through a detailed study of phylogeny related to ontogenesis was it possible to establish this fact.



TEXT-FIG. 3—A scheme of initial ontogenetic development of the suture line in agoniatites (*VU*-type).



TEXT-FIG. 4—A scheme of initial ontogenetic development of the suture line in goniatites (*VLU*-type).

The clymenias in general belong to the first type, although some representatives of this peculiar group appeared to complicate their septa by the second type. The first type was *initial also in evolution of all Mesozoic ammonoids* (ceratites and ammonites).

Unfortunately, the systematics of Mesozoic ammonoids are in an unsettled state. Due to the fact that a large majority of students on Triassic, Jurassic and Cretaceous ammonoids have underestimated the importance of ontogenetic investigations, there is no real phylogenetic system of these groups up to the present. If the students of ceratites and ammonites, instead of description and redescription of an infinite number of species, had studied ontogenesis with equal assiduousness, the classification of these groups would be in a much better state. Early ontogenetic development of the suture lines would be especially significant. Even with few available data it may be seen that the modes of complication of septa in Mesozoic groups are as variable as in Paleozoic ones.

Taxonomic subdivision of ceratites and ammonites can be based first of all upon different types of the second suture: $VU:ID$; $VUU^1:ID$; $(V_1V_1)UU^1:ID$; $(V_1V_1)U:ID$. Particularly is it necessary to emphasize that in all ceratites studied the second septum is formed according to the type *VU:ID*. Further, it is of great taxonomic importance that in some Mesozoic groups the primary internal lateral lobe (*I*) is situ-

ated next to the dorsal lobe; for instance, in the superfamily Perisphinctaceae. In others a second internal lateral lobe (I^1) appears early in ontogenetic development between the elements D and I; for example, in the superfamily Stephanocerataceae. Also, the subsequent complication of the suture line was attained in different ways: by the insertion of new umbilical lobes only, or by the formation both of umbilical and internal lateral lobes, or by evolving new internal lateral lobes alone. New elements complicating the suture might originate also by the subdivision either of saddles (symbols with upper figures) or of lobes themselves (symbols with lower figures). In addition, one more taxonomic feature should be mentioned; this is the modification of the dorsal lobe, which in all ceratites and earlier ammonites was bifid, but later became undivided at the base. All these and other transformations produced a great diversity of genetical types of the suture line characteristic for different taxa of the orders. The following examples serve to illustrate the patterns:

1. Complication by means of insertion of some umbilical lobes U. (In this and other cases the likeness of genera by a type of ontogenesis in itself does not mean taxonomic unity. While elaborating a system of ammonoids it is necessary to take into consideration earlier stages too. Genera similar at maturity may be greatly unlike at the earliest stages of individual development. So, for example, the genera *Strenoceras* and *Hypacanthoplites* have different second septa, the former $(V_1V_1)UU^1:ID$, the latter $(V_1V_1)U:ID$.)
   a. STRENOCERAS Hyatt, 1900 (Upper Bajocian)—$(V_1V_1)UU^1U^2:U^3ID$
   b. HYPACANTHOPLITES Spath, 1923 (Lower Albian)—$(V_1V_1)UU^1U^2U^3:U^4ID$
2. The same, but some umbilical lobes become completely subdivided:
   a. PERISPHINCTES Waagen, 1869 (Upper Oxfordian)—$(V_1V_1)UU^1U_1^2:U_1^2ID$
   b. CRASPEDITES Pavlow, 1892 (Upper Volgian) —$(V_1V_1)UU^1U_1^2U_1^3U_1^4U_1^5:U_1^5U_1^4U_1^3U_1^2ID$
3. Complication through appearance of the second internal lateral lobe I^1 and a number of umbilical lobes U:
   CADOCERAS Fischer, 1882 (Upper and Middle Callovian)—$(V_1V_1)UU^1U^2U_1^3U^4:U_1^3II^1D$
4. Complication by means of development of some internal lateral lobes I:
   DESHAYESITES Kazansky, 1914 (Aptian)—$(V_1V_1)UII^2:I^2I^1D$
5. The same, but some internal lateral lobes become completely subdivided:
   a. KOSMOCERAS Waagen, 1869 (Upper Callovian)—$(V_1V_1)UU^1I_1I^2I^3:I^4I_1I^1D$
   b. NORMANNITES Munier-Chalmas, 1892 (Middle Bajocian)—$(V_1V_1)UU^1II_2I_1I_1^3I_1^3:I_1^3I_1^2I_1I^1D$
6. Complication by asymmetrical subdivision of the primary umbilical and internal lateral lobes:
   CHELONICERAS Hyatt, 1903 (Upper Aptian) —$(V_1V_1)U_1U_2U^1I_2:I_1D$
7. Complication by evolving many umbilical lobes U and two external lateral lobes L; the primary umbilical lobe is subdivided into three independent lobes:
   METAPLACENTICERAS Spath, 1926 (Campanian)—$(V_1V_1)L^1LU_2U_1U_2U^1U^2U^4U^6:U^5U^3ID$
8. Complication by evolving many internal lateral lobes I and one external lateral lobe L:
   INDOCERAS Noetling, 1896 (Maestrichtian)—$(V_1V_1)LUII^2I^4I^6I^9I^{11}I^{13}I^{15}:I^{14}I^{12}I^{10}I^8I^6I^3I^1D$

Even these few examples should indicate the possibilities of a phylogentic system for ammonites, providing the ontogenetic method of investigation is used. Beyond reasonable doubt, it now appears that such further study of ceratites and ammonites in this fashion will lead to the establishment of a new system free of any polyphyletic conceptions. This key to understanding complex interrelations of different groups of Mesozoic ammonoids has long been known to students, but for some reason it has not been exploited.

One of the most important methods of solving phylogenetic systematics is the examination of taxa in their historical development. In this respect it may be emphasized that the comparison of peculiarities of organization used for taxonomic purposes cannot be made on a purely morphologic basis. The typologic approach is not admitted in studying either mature stages or early stages of growth. When analyzing ontogenetic data, it is necessary to take into account such phenomena as acceleration and retardation of development, skipping of intermediate stages, heterochrony, and heterotopy. In short, investigations must be based upon the study of evolution of ontogenesis.

The importance of such an approach seems to be clear from the following examples. In late representatives of the order Agoniatitida, owing to ontogenetic acceleration, the suture line $VUU^1:ID$ shifted from later stages back to the third septum, and the umbilical lobe (U) was displaced to the flanks. As a result of this transformation the lobes UU^1 came to occupy exactly the

same position in relation to the second septum as the lobes *LU* in late goniatites. This kind of development led to the wrong determination of symbols and consequently to taxonomic misplacement of some late agoniatites. The same can be said concerning representatives of the order Ammonitida. In many of them, as a result of a great shift to early stages, the second suture line obtained the formula $(V_1V_1)UU^1{:}ID$. This pattern can be wrongly interpreted as $(V_1V_1)LU{:}ID$. and it has been done more than once. This misunderstanding is due to the fact that the stages indicating development according to the first type have been excluded completely from ontogenesis. The truth then can be arrived at only by studying the overall history of ammonoids, and recognizing the direct relationship of the orders Agoniatitida, Ceratitida, and Ammonitida.

Up to the present, ontogeny of ammonites has been neglected, although it is apparent that no problem in ammonoid classification is more important. Nevertheless, it is necessary to emphasize that in dealing with ontogenetic data, if the question of taxonomic position of any group is to be solved, one must always keep the evolution of all ammonoids in mind.

ORDERS OF AMMONOIDS

Existing knowledge concerning onto-phylogenetic development of ammonoids convincingly indicates that this group consists of five orders each possessing fundamental features of organization which determine phylogenetic unity of subordinate taxa. Each order has its particular type of early ontogenesis, a main link in spite of diversity of subsequent developmental transformations. The most typical and common feature, hence, is to be selected as the basis for definition of an order.

Order AGONIATITIDA. Shell of different form, chiefly discoidal or lenticular. Siphuncle ventrally situated, marginal at all stages of growth. Septum developed according to the type $VO{\rightarrow}VU$, *i.e.*, next to the ventral lobe first the omnilateral and then the umbilical lobe is situated. Ventral lobe either simple or trifid, even if in ontogenesis it developed according to the formula $V{\rightarrow}(V_2V_1V_2)$, or extremely rarely it is bifid. Dorsal lobe either simple or bifid. The second suture line in the course of evolution attained the state corresponding to the formula $VU{:}D$. Complication of the septum resulted from insertion of the lobe *I*, but mostly of the lobes *U* which arose in the zone of umbilical seam. Lobes migrated from there successively and alternatively; first outward, toward the ventral lobe, and then inward, toward the dorsal lobe. In some cases new lobes developed from the secondary ventral saddles, shifting subsequently toward the umbilical lobes. Still more rarely an incomplete subdivision of the primary umbilical lobe took place. The number of umbilical lobes may be very great. *Lower Devonian—Upper Triassic.*

Order GONIATITIDA. Shell of variable form. Siphuncle, with rare exception, is ventral and marginal at all stages of growth. Only some representatives of the superfamily Cheiloceratacеae (*Maximites, Neoaganides, Pseudohalorites*) have the siphuncle shifted from the venter toward the dorsum, without reaching it. The other exception is the genus *Agathiceras* in which the siphuncle is central during early ontogenetic stages; with growth it reoccupies a normal ventral position. Septum developed according to the type *VLU*, *i.e.* the external lateral lobe arose between the ventral and umbilical lobes. Ventral lobe either simple, very rarely trifid, or commonly bifid according to the formula $V{\rightarrow}(V_1V_1)$. Dorsal lobe either simple or bifid (very rarely) or trifid. The second suture line had the formula $VU{:}D$. Many families of this order maintained a constant number of lobes, eight in total for a septum. The suture line developed complications not by insertion of new elements but by modification of shape of the principal lobes; these were elongated, widened, acquired a constriction above and an offshoot below, became dome-shaped, trifid, multidentate, and so on. In other families the septum underwent more complex transformations through formation of new lobes. Such elements arose from the primary external lateral, umbilical and internal lateral lobes as a result of their single or reiterative subdivision into three or two parts. New lobes separated from the primary lobes *L* and *I* moved with the expansion towards the umbilicus. The number of lobes arising in such a manner may be very great. *Middle Devonian—Upper Permian* (to the end of this epoch).

This order differs from the Agoniatitida by many peculiarities of development which are displayed from the earliest ontogenetic stages. In each of the two orders, the suture lines underwent diverse transformations and complications which serve as the principal criterion for establishing suborders, superfamilies and families. However, the modes of transformation were totally different in representatives of the two orders. In agoniatites (*VU*-type), the complication of the septum was achieved through the lobes *U* that were shifted on the outside from the umbilicus to the venter. In goniatites (*VLU*-type), the umbilical lobe also took part in the complication of the septum, but the highest organization was attained through the elements *L* and *I*. New lobes arose by the subdivision of the external lateral lobe moving in the opposite direction, from the venter to the umbilicus. Other differences may be shown. In considering the more advanced forms, we can observe that in agoniatites the ventral lobe became trifid and the dorsal one bifid; in goniatites, on the contrary, the ventral lobe became bifid and the dorsal one trifid. Exceptions to this rule are so rare that they have no influence upon the general characteristic of the orders. Finally, it may be worthy of mention that even in the most highly organized agoniatites the lobes are serrated only at the base, whereas in some goniatite families lobes are complicated by additional saddles up to the top.

Order CLYMENIIDA. Shell of variable form, sometimes with triangular coiling of whorls. Siphuncle dorsal and marginal at all stages of growth. The trends of evolution of the septum were unstable and variable, but there were two main directions: by the type $VU \rightarrow VLU$ (the lobe *L* never outgrew the umbilical one) and by the type $VU \rightarrow U$. Ventral lobe either simple or widely bifid, or entirely absent, being replaced in ontogenesis by a ventral saddle. Dorsal lobe either simple or, as an extreme rarity, widely bifid; in one genus it disappears and is replaced by a dorsal saddle. The second suture line, according to the available data, had the formula *VU:D*. In the course of evolution the suture line underwent both complication and simplification. The complication advanced through formation of the lobes *I*, *U* and *L* and was quite limited, although variable in form; the number of all lobes never exceeds 12. The simplification ensued from disappearance (in ontogenesis) of the ventral and even of the dorsal lobe. The most degraded septa of clymenias imitate those of the oldest agoniatites but in a reverse pattern: in initial agoniatites there is a ventral lobe and the dorsal one is absent (*VO*), whereas in primitive clymenias there is a dorsal lobe and the ventral one is absent (*UD*); the lobe *U* became so broad that it imitates the form of the omnilateral lobe of agoniatites. *Upper Devonian—the base of Lower Carboniferous* (of Tournaisian stage).

It differs from the orders Agoniatitida and Goniatitida by dorsal position of the siphuncle and also by peculiar development of the suture line.

Order CERATITIDA. Shell greatly variable in form and sculpture. Siphuncle may be central during early stages of growth but at maturity always ventral and marginal. Septum developed according to the type $(V_1V_1)U$, *i.e.*, next to the ventral lobe is situated the umbilical one. Ventral lobe divided into two parts. Dorsal lobe primarily bifid. The second suture line had the formula *VU:ID*. Complication of septum ensued from insertion of the lobes *I*, but mostly from the lobes *U* arising in the zone of umbilical seam; from where they shifted successively and alternatively first toward the ventral lobe and then toward the dorsal lobe. In latest representatives there occurred also other modes of complication. Lobes, as a rule, ceratitic, although some were undivided or ammonitic. *Lower Permian—Upper Triassic.*

The taxon Ceratitida differs from the order Agoniatitida by the bifid subdivision of the ventral lobe, more complicated second suture line, and a general direction of development. From Goniatitida it differs by the absence of an external lateral lobe and by presence of a more complicated second suture line. The venral position of the siphuncle and much higher general organization serve to distinguish this order from the Clymeniida.

Order AMMONITIDA. Shell extremely variable in form and sculpture. Siphuncle unstable in position at early stages, but at maturity it is always ventral and marginal. Septum, as in ceratites, developed according to the type $(V_1V_1)U$. Ventral lobe di-

vided into two parts. Dorsal lobe either bifid (original type) or with an unpaired termination, although having more or less complicated sides. The second suture line had the formula $VUU^1:ID \rightarrow (V_1V_1)UU^1:ID$; in late types with retarded or reverted development, the number of lobes may be fewer. Complication of septum produced in many fashions, through insertion of the lobes *U*, *I* and *L* as well as by appearance of adventitious lobes at the top of saddles. Different modes of suture complication may be of most value for subdivision of the order into suborders, superfamilies and families. Lobes, as a rule, of ammonite type, although very rarely they are ceratitic or even goniatitic. *Lower Triassic—Upper Cretaceous.*

This group differes from the other orders by a more complicated second suture line. At the beginning of the phylogenetic history there are eight lobes around this septum instead of the six in ceratites and four in more ancient orders. In addition, the suture line in ammonites is on the whole more advanced and of more complicated pattern.

REFERENCES

ARKELL, W. J., 1957, Introduction to Mesozoic Ammonoidea: Treatise on Invertebrate Paleontology, Pt. L, p. 81–129.

BESNOSSOW, N. V., 1958, Jurassic ammonites of North Caucasus and Crimea, p. 1–118 (In Russian).

BOGOSLOVSKY, B. I., 1958, Devonian ammonoids of Rudnyi Altai: Trudy Paleontologicheskogo Instituta, v. 64, p. 1–155 (In Russian).

DIENER, C., 1916a, Bemerkungen über die Inzisionen der Suturlinie als Grundlage einer natürlichen Klassifikation der Ammoniten: Centralb. f. Min., Geol. u. Paläont., p. 374–381.

——, 1916b, Einiges über Terminologie und Entwicklung der Lobenelemente in der Ammonitensutur: Ibid., p. 553–568; 578–592.

DRUŻCZIC, V. V., 1956, Lower Cretaceous ammonites of Crimea and North Caucasus, p. 1–150 (In Russian).

NOETLING, F., 1905, Über die Ontogenie von *Indoceras baluchistanense* Noetling: Neues Jahrb. f. Min. usw., H. 1, p. 1–14.

——, 1906, Die Entwickelung von *Indoceras baluchistanense* Noetling. Ein Beitrag zur Ontogenie der Ammoniten: Geol. u. palaeont. Abhand., n.f., Bd. 8, H. 1, p. 1–96.

RUZHENCEV, V. E., 1949a, Systematics and evolution of the families Pronoritidae Frech and Medlicottiidae Karpinsky: Trudy Paleontologicheskogo Instituta, v. 19, p. 1–206 (In Russian).

——, 1949b, Main types of evolutional changes of the suture line in Upper Paleozoic ammonites: Ibid., v. 20, p. 183–198 (In Russian).

——, 1950, Upper Carboniferous ammonites of the Urals: Ibid., v. 29, p. 1–220 (In Russian).

——, 1951, Lower Permian ammonites of the Southern Urals. 1. Ammonites of the Sakmarian stage: Ibid., v. 33, p. 1–188 (In Russian).

——, 1956, Lower Permian ammonites of the Southern Urals. II. Ammonites of the Artinskina stage: Ibid., v. 60, p. 1–274 (In Russian).

——, 1957, Phylogenetic system of the Paleozoic ammonoids: Bull. Soc. Natur. Moscou, sec. géol., t. 32, no. 2, p. 49–64 (In Russian).

SCHINDEWOLF, O. H., 1928, Zur Terminologie der Lobenlinie: Paleont. Zeitschr., Bd. 9, p. 181–186.

——, 1929, Vergleichende Studien zur Phylogenie, Morphogenie und Terminologie der Ammoneenlobenlinie: Abhand. preuss. geol. Landesanst,. n. f., H. 115, p. 1–102.

——, 1933, Vergleichende Morphologie und Phylogenie der Anfangskammern tetrabranchiater Cephalopoden: Ibid., H. 148, p. 1–122.

——, 1951, Zur Morphogenie und Terminologie der Ammoneen-Lobenlinie: Paläont. Zeitschr., Bd. 25, p. 11–34.

——, 1953, Über *Strenoceras* und andere Dogger-Ammoniten: Neues Jahrb. f. Geol. u. Paläont., Mh. 3, p. 119–130.

——, 1954a, On development, evolution, and terminology of ammonoid suture line: Bull. Mus. Compar. Zoology, v. 112, no. 3, p. 217–237.

——, 1954b, Über die Lobenlinie der Ammonoidea: Neues Jahrb. f. Geol. u. Paläont., Mh. 3, p. 123–140.

——, 1957, Die Lobenlinie im System der Ammonoidea: Ibid., Mh. 10, p. 433–443.

SCHMIDT, H., 1921, Über Goniatiten—eine Revision ihrer Systematik mit Beifügung neuer Beobachtungen: Centralbl. f. Min. usw., p. 538–544.

——, 1925, Die carbonischen Goniatiten Deutchlands: Jahrb. preuss. geol. Landesanst., Bd. 45, p. 489–609.

——, 1934, Cepahlopodenfaunen des älteren Namur aus der Umgegend von Arnsberg in Westfalen: Ibid., Bd. 54, p. 440–461.

——, 1952, *Prolobites* und die Lobenentwicklung bei Goniatiten: Paläont. Zeitschr., Bd. 26, p. 205–217.

WEDEKIND, R., 1913a, Beiträge zur Kenntnis des Oberdevon am Nordrande des Rheinischen Gebirges. 2. Zur Kenntnis der Prolobitiden: Neues Jahrb. f. Min. usw., H. 1, p. 78–95.

——, 1913b, Die Goniatitenkalke des unteren Oberdevon von Martenberg bei Adorf: Sitzungsb. Geselsch. naturf. Freunde Berlin, Jahrg. 1913, p. 23–77.

——, 1914, Beiträge zur Kenntnis der oberkarbonischen Goniatiten: Mitteil. Mus. Stadt Essen, H. 1, p. 1–23.

——, 1916a, Über Lobus, Suturallobus und Inzision: Centralbl. f. Min. usw., p. 185–195.

——, 1916b, Zur Systematik der Ammonoidea: Ibid., p. 529–538.

——, 1918, Die Genera der Palaeoammonoidea (Goniatiten): Palaeontographica, Bd. 62, p. 85–184.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 620–636, PLS. 71–77, JULY, 1960

DEVONIAN STROMATOPOROIDS FROM THE LOWER MACKENZIE VALLEY OF CANADA

J. J. GALLOWAY
Indiana University, Bloomington

ABSTRACT—Twenty-four species of Middle and Upper Devonian stromatoporoids, belonging to twelve genera, are described and illustrated from the area between Norman Wells and Fort Good Hope in the lower Mackenzie Valley. The stromatoporoids agree specifically with those from Iowa, Indiana, England, Belgium, and Germany, from the lower Middle and lower Upper Devonian. Five new species were identified.

INTRODUCTION

ALTHOUGH Devonian stromatoporoids have long been known from the Northwest Territories, Canada, only one species, *Trupetostroma warreni* Parks, from Great Slave Lake, seems to have been identified from that vast area; *Actinostroma whiteavesi* Nicholson is from "Little Red River," now Peace River, northern Alberta.

The material herein described and figured was submitted to the author for study by B. F. Howell, of Princeton University. The material was collected by A. C. Lenz in 1958, when he was employed by the California Standard Company of Calgary, Alberta; all concerned have given permission for publication. The specimens and slides are the property of Princeton University; portions of the specimens and slides of the new species, and some others, are also in the Indiana University Paleontological Collections.

There were 26 specimens of proper size for sectioning, embracing 12 genera and 23 species, to which is added one specimen of *Trupetostroma warreni* from the Kee Scarp Reef of the Fort Creek shale. The collection was not exhaustive, but it may well be a good sampling of the forms occurring in the region. The material is remarkable in two ways. First, it is well preserved by infiltration of calcium carbonate, with little leaching or dolomitization, which affects most Western specimens, and only the beginning, in some cases, of silicification. Secondly, it is remarkable in that most of the species have been described as occurring in the Middle Devonian, lower Hamilton, Eifelian and Givetian, and lower Upper Devonian, Frasnian, of Manitoba, Indiana, Iowa, England, Belgium, Germany, and Russia. New stromatoporoid faunas are largely new species. Nineteen species are from the Middle Devonian, Eifelian and Givetian, in, below, or above the *Stringocephalus* Beds. There are four species from the Middle Devonian Kee Scarp Reef. Two species are attached to two other species of stromatoporoids.

There seems to be no species in common between the Mackenzie Valley species and those from the Abitibi River limestone (Fritz & Waines, 1956). Only one is common with the form from Sandusky, one with

EXPLANATION OF PLATE 71

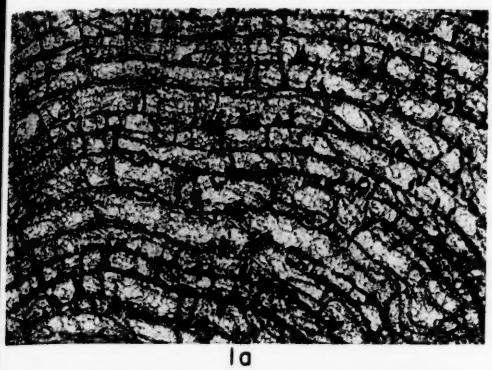
All figures ×10. Specimens and slides are in Princeton University. Figures have been slightly retouched.

FIGS. *1*—*Anostylostroma vacuolatum* Galloway, n. sp. *a*, Normal vertical section; *b*, vertical section crushed near the top; and *c*, tangential section. Post-*Stringocephalus* Beds. Holotype, P. U., 81707, slide MV1-1.

2—*Stromatoporella eriensis* (Parks). *a*, Slightly oblique, vertical section, split horizontally; and *b*, normal tangential section. *Radiastrea* Zone. P. U., 83018, slide MV1-2.

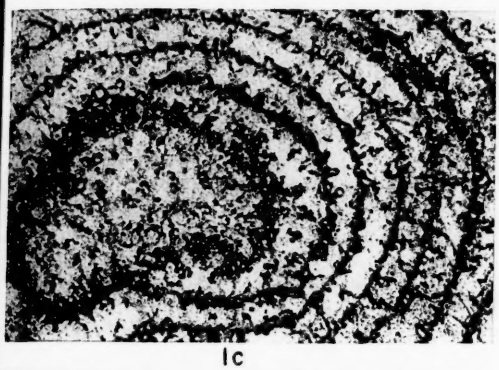
3—*Stromatoporella eriensis* (Parks). *a*, Vertical section; and *b*, tangential section with some ring pillars attached to vermicular pillars. *Radiastrea* Zone, P. U., 83007, slide MV1-3.

4—*Stromatoporella damnoniensis* Nicholson. Vertical section through a mamelon. Kee Scarp Member. P. U., 83011, slide MV1-6.

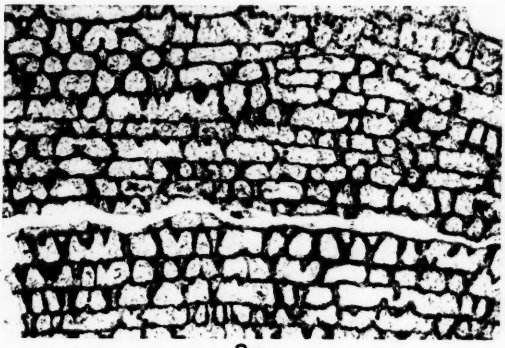


1a

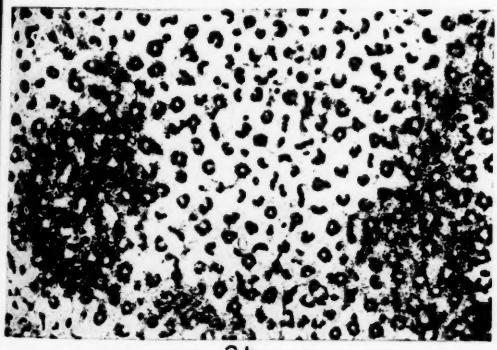
1b



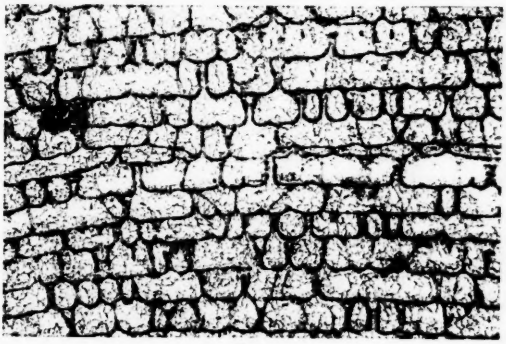
1c



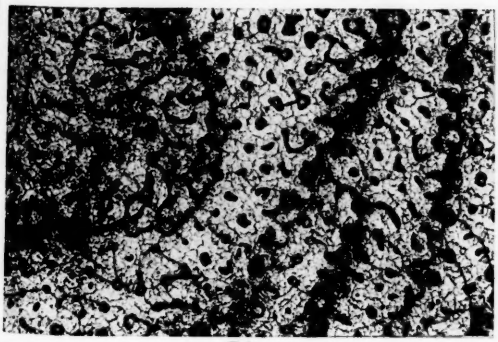
2a



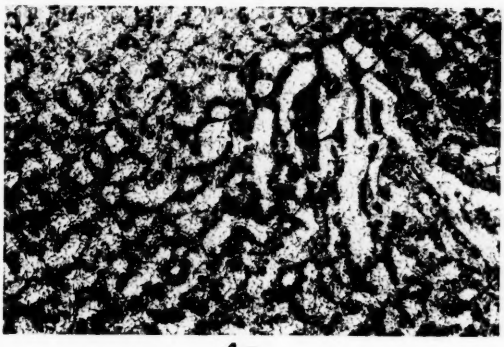
2b



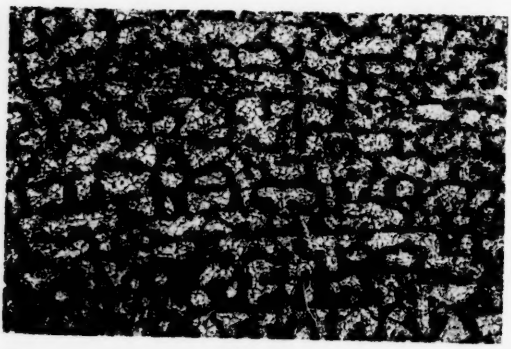
3a



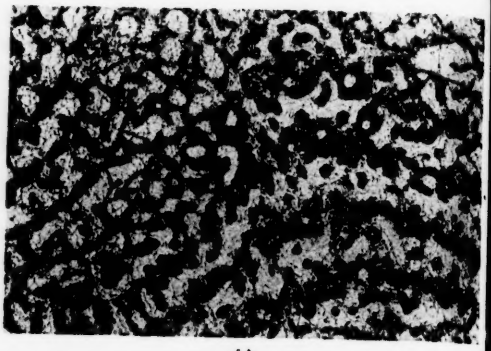
3b



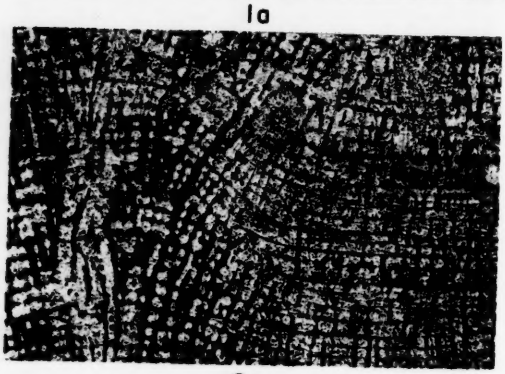
4a



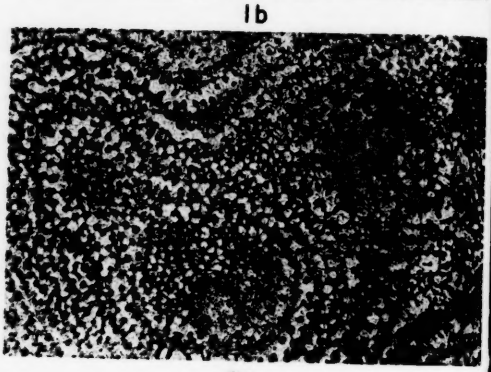
1a



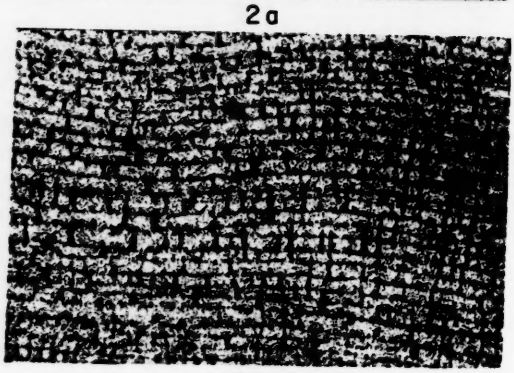
1b



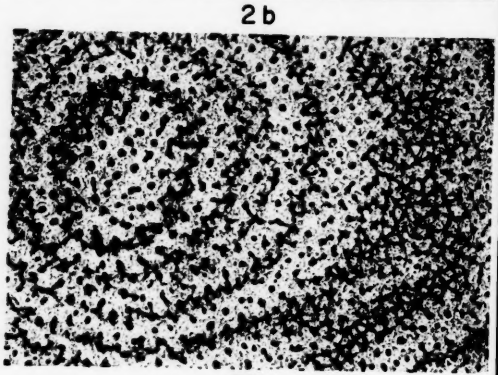
2a



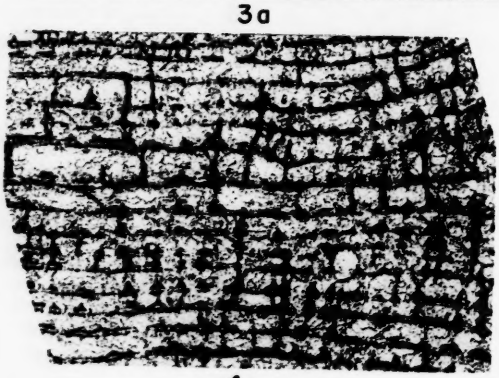
2b



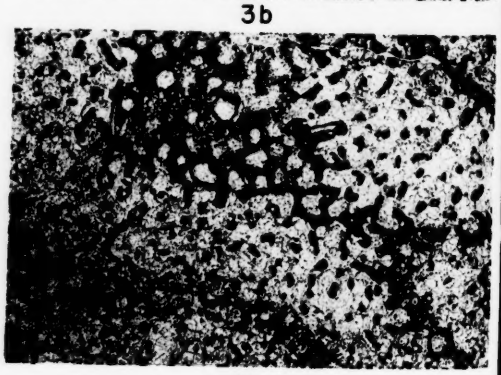
3a



3b



4a



4b

forms from Columbis, Ohio, and none with the Onondaga forms from Ontario, New York, Michigan (Detroit River), Indiana, or Kentucky (Jeffersonville). Few of the species are in common with the upper Hamilton, Traverse Group of Michigan.

The latilaminae, which are annual layers of growth, are mostly thin, 2 to 5 mm., and all thinner than in most stromatoporoids, indicating a mild climate, but have no systematic significance. Most stromatoporoids lived in shallow clear warm water, exposed to wave action and temperature changes with the seasons, causing the latilaminae or *stroma*, for which character the order was named. Stromatoporoids thrived in shallow rough water and made reefs. Many of the Mackenzie Valley occurrences are in reefs.

The following species were identified from the five horizons.

STROMATOPOROIDS FROM THE LOWER MACKENZIE VALLEY

	Locality—Cat. No.
Radiastrea arachne ZONE, LOWER MIDDLE DEVONIAN, EIFELIAN	
Clathrocoilona restricta G. & St. J.	L30. 83705
Ferestromatopora jacquesensis Galloway, n. sp.	S47. 83008
Stromatopora cf. *S. maculata* Lecompte	K72B. 83009
Stromatoporella eriensis (Parks)	K160. 83018; L7. 83007
Syringostroma sanduskyense G. & St. J.	L11. 82703
Talestroma lenzi Galloway, n. sp.	L11. 83004
Trupetostroma cf. *T. coalescens* G. & St. J.	S47. 83008
Rensselandia laevis ZONE, EIFELIAN	
Parallelopora pellucida (Yavorsky)	L14. 83005
Taleastroma conicomamillata (G. & St. J.)	L14. 82704
Taleastroma vitreum Galloway, n. sp.	L14. 83005
Stringocephalus burtini BEDS, GIVETIAN	
Actinostroma tyrrelli Nicholson	L15. 83003
Actinostroma aff. *A. tyrrelli* Nicholson	L14. 82706
Parallelopora ostiolata Bargatzky	K122. 83001
Stromatopora arcuata Galloway, n. sp.	K101. 83006
Stromatopora hüpschi (Bargatzky)	L124. 82710
Syringostroma sanduskyense G. & St. J.	L14. 82702
Trupetostroma coalescens G. & St. J.	L14. 83002; K122. 82711
Trupetostroma iowaense Parks	L14. 82709
Trupetostroma maillieuxi Lecompte	L124. 83019
Post-Stringocephalus burtini BEDS, POSSIBLY UPPER DEVONIAN	
Anostylostroma vacuolatum Galloway, n. sp.	L14. 82707
Hermatostroma episcopale Nicholson	L14. 83017
Trupetostroma porosum Lecompte	L14. 82708
KEE SCARP REEF ZONE, LOWER UPPER DEVONIAN, FRASNIAN	
Clathrocoilona abeona Yavorsky	L1. 83015
Stromatopora planulata (Hall & Whitfield)?	L1. 82016
Stromatoporella damnoniensis Nicholson	L2. 83010, 83011
Trupetostroma warreni Parks	I. U. 5380

EXPLANATION OF PLATE 72

All figures ×10

FIGS. *1*—*Stromatoporella damnoniensis* Nicholson. *a*, Vertical section, showing thick laminae, pillars and ring-pillars formed by rises of laminae, and pores in the tissue; and *b*, tangential section, showing large ring-pillars. Kee Scarp Reef. P. U., 83011, slide MV1-6.

2—*Actinostroma tyrrelli* Nicholson. *a*, Vertical section, showing normal laminae and pillars, and larger pillars and narrow tubes in the astrorhizal columns; and *b*, tangential section. *Stringocephalus* Beds. P. U., 83003, slide MV1-7.

3—*Actinostroma* aff. *A. tyrrelli* Nicholson. *a*, Vertical section; and *b*, tangential section. *Stringocephalus* Beds. P. U., 82706, slide MV1-8.

4—*Trupetostroma warreni* Parks. *a*, Vertical section; and *b*, tangential section. Kee Scarp Reef. Indiana University, no. 5380, slide 282-26.

SYSTEMATIC DESCRIPTIONS

Order STROMATOPOROIDEA Nicholson & Maurie, 1878

Family CLATHRODICTYIDAE Kühn, 1939

Genus ANOSTYLOSTROMA Parks, 1936

Type: *A. hamiltonese* Parks, 1936.

Coenosteum massive; laminae regular; pillars short, expanding upward; tissue compact, fibrous or porous, not maculate.

ANOSTYLOSTIOMA VACUOLATUM Galloway, n. sp.

Pl. 71, figs. 1a,b,c

Exterior.—Coenosteum massive; surface with small, variable mamelons, 3 to 5 mm. in diameter; astrorhizae scattered, rarely with vertical tubes.

Vertical section.—Laminae thin, 6 in 2 mm., undulating, composed of three thin layers, a median thin, clear, even microlamina, and thin, irregular, secondary deposits both above and below the microlamina. Pillars thin, 6 to 12 in 2 mm., thicker at the base, only incidentally superposed, some not reaching the next lamina because the section is not cut exactly vertically. Galleries rectangular, many with thin dissepiments, which are oblique, curved upward or flat. In some mamelons, there is a vertical tube with lateral branches, but otherwise astrorhizae are not apparent. The tissue is mostly compact, but in places there are fine pores which pass vertically through all three layers of the laminae. In the secondary layers, both above and below the median microlamina, there are round vacuoles of variable size, 0.03 to 0.1 mm. in diameter, with walls of irregular thickness, which suggest the name *Anostylostroma vacuolatum.* In places, the laminae and pillars have been disturbed by shearing, as seen in Park's figures of another species (1936, pl. 4, figs. 2,3).

Tangential section.—The annuli of laminae emphasize the round and variable mamelons. The laminae are thin but with variable amounts of thickening, and the clear, round vacuoles are numerous, 0.03 to 0.1 mm. in diameter. Pillars irregular, mostly with a large round vacuole. There are no astrorhizal canals or vertical tubes in the mamelon columns in our sections.

Occurrence.—Post-*Stringocephalus* Beds, Ramparts formation 240–345 feet above base, possibly Upper Devonian, near Fort Good Hope, Northwest Territories; Lenz locality L14. Princeton University, no. 82707, slide MV1-1. Fragment in Indiana University, slide 307-75.

Genus STROMATOPORELLA Nicholson, 1886

Type: *S. granulata* (Nicholson), 1886; Galloway, 1957.

Coenosteum massive; laminae rising into ring-pillars, making large rings in tangential section; pillars short, not superposed; tissue porous or with anastomosing tubules, not maculate.

STROMATOPORELLA ERIENSIS (Parks)

Pl. 71, figs. 2a,b; 3a,b

Stictostroma eriensis PARKS, 1936, Univ. Toronto Studies, geol. ser., no. 39, p. 81, pl. 5, figs. 1–4 (Mid. Dev., Columbus limestone, Marblehead, Ohio).

Exterior.—Coenosteum massive; surface without mamelons or astrorhizae; latilaminae about 5 mm. thick.

Vertical section.—Laminae rather thin, 7 and 2 mm., rising regularly into ring-pillars the full height of the chambers. Tissue transversely fibrous and definitely porous; Parks says that the laminae are nonporous. Galleries higher than wide, excepting where pillars are not encountered in the section. Dissepiments scarce, crossing the galleries obliquely.

Tangential section.—The laminae are thick and show the vertical pores. Ring-pillars abundant and conspicuous, mostly simple rings about 0.3 mm. in diameter, and there are also round and vermicular pillars, some joined by dissepiments.

Remarks.—The Mackenzie Valley examples of this species appear to be typical, although the horizon may be a little higher than the Columbus limestone of Marblehead, Ohio.

Occurrence.—A good specimen from the "Lower Ramparts" formation, Middle Devonian, *Radiastrea arachne* Zone, Carcajou Ridge, 20 miles northwest of Norman Wells; Lenz locality K160. Princeton University, no. 83018. Another specimen from the same region, locality L7, no. 83007, seems identical in the vertical sections but in the tangential section many of the ring-pillars

are imperfect and attached to vermicular pillars. More sections and more material would likely show that the two specimens are the same species. Slides MV1-2,3.

STROMATOPORELLA DAMNONIENSIS Nicholson
Pl. 71, fig. 4a; Pl. 72, figs. 1a,b

Stromatoporella damnoniensis NICHOLSON, 1886a, Ann. Mag. Nat. Hist., ser 5, v. 17, p. 237, pl. 8, figs. 3,4 (Mid. Dev., Devonshire); 1892, Palaeontological Soc. London, v. 46, p. 207, pl. 27, figs. 8,9.

Exterior.—Coenosteum massive; surface with low, conoidal mamelons, 4 to 6 mm. in diameter and 6 to 8 mm. apart. Latilaminae 4 to 7 mm. thick. Astrorhizae not apparent.

Vertical section.—The laminae are thick, 0.1 to 0.2 mm., 6 to 7 in 2 mm., coarsely porous transversely, regular and rising sharply over the mamelons, and also rising at short intervals into ring-pillars. Simple pillars short, not superposed, some straight, many variable in thickness and direction, about as thick as the laminae. Galleries oval, elongate or round, slightly higher than the laminae are thick, many with foramina between. The mamelons are about 4 mm. high, do not make columns but are restricted to a single latilamina, some with a short vertical tube or several tubes, not definitely astrorhizae. Dissepiments scarce.

Tangential section.—Laminae thick, irregular, and porous. Ring-pillars large, thick-walled, 0.3 to 0.5 mm. outside with lumina 0.15 mm. in diameter, abundant in places. Galleries irregular, vermicular and anastomosing. Astrorhizae not typically developed. Dissepiments scarce.

Comparisons.—This species is characterized by the thick laminae, the discontinuous mamelons, large ring-pillars, imperfect astrorhizae and porous tissue. The Norman Wells specimens seem identical with Nicholson's type, but the latter does not have well-developed astrorhizae as stated by Lecompte (1951, p. 183, 184) who gives the age as Lower Frasnian.

Occurrence.—Two fragments, apparently from the same specimen, from the Kee Scarp member of the Fort Creek shale, 1 to 80 feet above the base, Middle Devonian, Norman Wells, Northwest Territories. Collected by A. C. Lenz, 1958, locality L2. Princeton University, nos. 83010, 83011, slides MV1-4,5,6. Indiana University, fragment and slide 307-96.

Family ACTINOSTROMATIDAE Nicholson, 1886
Genus ACTINOSTROMA Nicholson, 1886
Type: *A. clathratum* Nicholson, 1886b; Galloway, 1957.

Coenosteum massive; pillars continuous, with radical processes at concordant levels, forming laminae; tissue compact.

At least 132 species have been assigned to *Actinostroma*, according to Erik Flügel (1958), of which 23 do not belong in the genus, 13 forms are unrecognizable, 34 are recognized as good species and 39 are synonyms. Many species are insufficiently characterized. Therefore, the identifications of the two Mackenzie Valley species must remain in doubt until Dr. Flügel completes the monograph of the genus, on which he is now engaged.

ACTINOSTROMA TYRRELLI Nicholson
Pl. 72, figs. 2a,b

Actinostroma tyrrelli NICHOLSON, 1891b, Ann. Mag. Nat. Hist., ser. 6, v. 7, p. 317 (Mid. Dev., Givetian, Lake Winnepegosis, Manitoba); GALLOWAY & ST. JEAN, 1957, Am. Paleontology, Bull., v. 37, no. 162, p. 150.

Exterior.—Coenosteum bulbous, 50 mm. in diameter, with an obconical stem 20 mm. long and 15 to 20 mm. in diameter. Surface with small, low, conical mamelons, about 3 mm. in diameter and 5 mm. apart from center to center. Each mamelon (shown by smoothed surface) has a minute astrorhiza about 1 mm. in diameter. Latilaminae obscure, 2 to 4 mm. thick.

Vertical section.—The laminae are thin and curve gently over the mamelon columns, 12 to 15 in 2 mm. The pillars are nearly twice as thick as the laminae, 0.06 to 0.08 mm. in diameter, about 12 in 2 mm., and make a regular quadrangular meshwork with the laminae. There are narrow astrorhizal columns, 0.5 mm. wide, in which the pillars are thicker, surrounding several narrow astrorhizal tubes. Dissepiments absent. The specimen has several parasitic worm tubes, 0.5 mm. in diameter, which make vertically enlarging spirals.

Tangential section.—The laminae are composed of the regular radiating arms of the pillars; the arms are about half the width

of the pillars, about 12 pillars in 2 mm., which have no central tube. The laminae make annuli about the mamelons, and in some mamelons there are radiating lines of pillars, indicating astrorhizae, and in other mamelons there is a tube about 0.25 mm. in diameter, surrounded by pillars. The tissue of the pillars is compact with minute dust-like particles (not maculae, which are much larger).

Comparisons.—This species is well characterized by the fine, regular meshwork of laminae and pillars; the small mamelons with minute column and tubes and minute astrorhizae. Pillars are thicker, mamelons smaller than in *Actinostroma stellulatum*. The specimen is similar to the type of *A. tyrrelli*, but has fewer laminae in 2 mm. and larger pillars, particularly in the mamelons. It has much smaller astrorhizae than *A. stellulatum*.

Occurrence.—A perfect specimen, well preserved, is from the *Stringocephalus* Beds (Givetian) of the Ramparts formation, 15 miles north of Fort Good Hope, Northwest Territories, Lenz locality L15. Princeton University, no. 83003, slide MV1-7. Indiana University, slides 307-76,77.

ACTINOSTROMA aff. A. TYRRELLI Nicholson
Pl. 72, figs. 3a,b

Actinostroma tyrrelli NICHOLSON, 1891b, Ann. Mag. Nat. Hist., ser. 6, v. 7, p. 317 (Mid. Dev., Givetian, Lake Winnepegosis, Manitoba); GALLOWAY & ST. JEAN, 1957, Am. Paleontology, Bull., v. 37, no. 162, p. 150.

Exterior.—Coenosteum massive; surface with low amelons 3 to 5 mm. in diameter and 8 to 10 mm. apart from crest to crest. Latilaminae about 2 mm. thick. Astrorhizae indistinct, minute, in the summits of the mamelons.

Vertical section.—The laminae and pillars are about the same strength and make a rectangular meshwork, 12 to 15 laminae in 2 mm., and about 12 pillars in 2 mm. Laminae not continuous, being indicated by the radial arms at concordant levels. Pillars without central tube, thickening slightly at each laminae, 0.04 to 0.1 mm. thick. Dissepiments absent.

Tangential section.—The laminae make broad annuli about the centers of the mamelons. In some mamelons there is an imperfect astrorhiza with about 8 short arms, in others a tube about 0.5 in diameter, but astrorhizae are in general rare.

Comparisons.—The specimen has larger mamelons and fewer astrorhizae than typical *Actinostroma tyrrelli*. It has much smaller and fewer astrorhizae than *A. stellulatum*, which it somewhat resembles.

Occurrence.—A fragmentary, well preserved specimen from the *Stringocephalus* Beds of the Ramparts formation, 220 feet above the base, on the Mackenzie River, near Fort Good Hope. Collected by A. C. Lenz, 1958, Lenz locality L14. Princeton University, no. 82706, slide MV1-8. Indiana University, slide 307-80.

Genus TRUPETOSTROMA Parks, 1936
Type: *T. warreni* Parks, 1936; Galloway, 1957.

Coenosteum massive; tissue compact, with vacuoles; laminae typically tripartite; both pillars and galleries superposed; in tangential section pillars continguous, surrounding galleries; pillars without arms. Mamelons and astrorhizae may occur. *Trupetostroma* lacks the radiating arms of *Actinostroma* and lacks the porous tissue of *Gerronostroma*.

EXPLANATION OF PLATE 73
All figures ×10

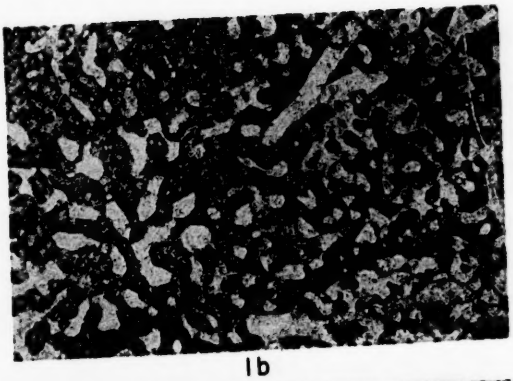
FIGS. *1*—*Trupetostroma iowaense* Parks. *a*, Vertical section; and *b*, tangential section. *Stringocephalus* Beds. P. U., 82709, slide MV1-9.

2—*Trupetostroma porosum* Lecompte. *a*, Vertical section; and *b*, tangential section. Post-*Stringocephalus* Beds. P. U., 82708, slide MV1-10.

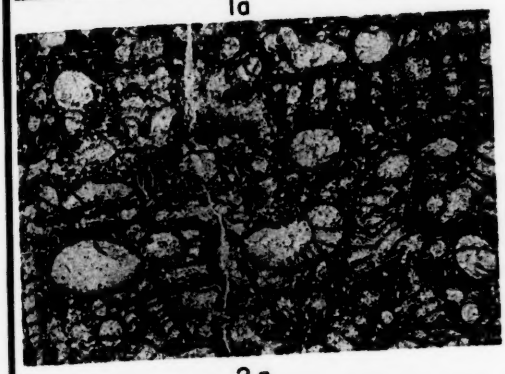
3—*Trupetostroma maillieuxi* Lecompte. *a*, Vertical section; and *b*, oblique tangential section. *Stringocephalus* Beds. P. U., 83019, slide MV1-11.

4—*Trupetostroma coalescens* Galloway & St. Jean. *a*, Vertical section; and *b*, tangential section, confluent, dark pillars in laminae, round, light, coalescent, between laminae; round galleries and small astrorhizal canals. *Stringocephalus* Beds. P. U., 83002, slide MV1-12.

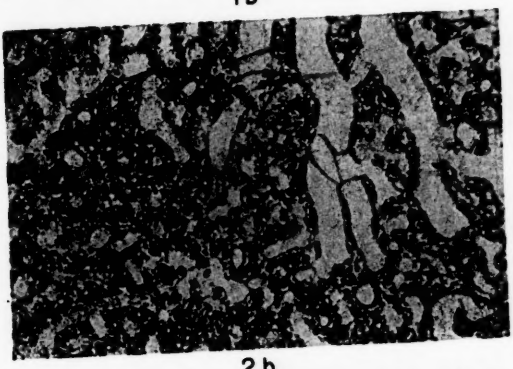
1a



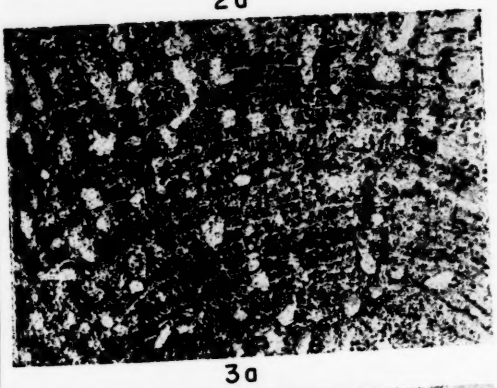
1b



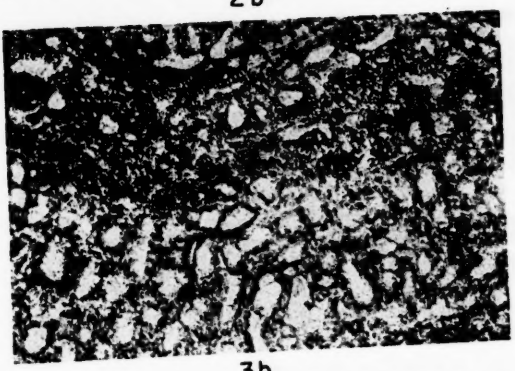
2a



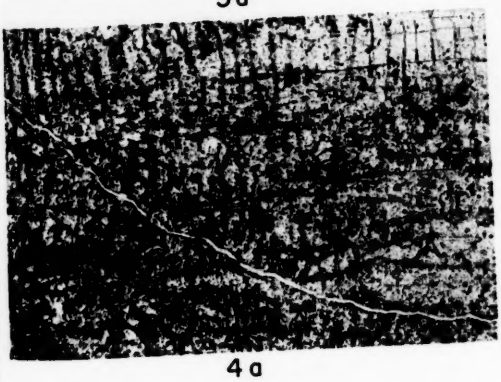
2b



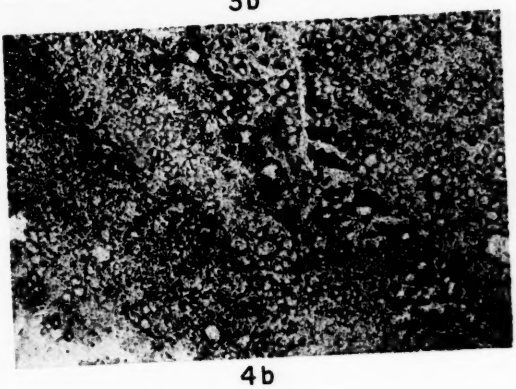
3a



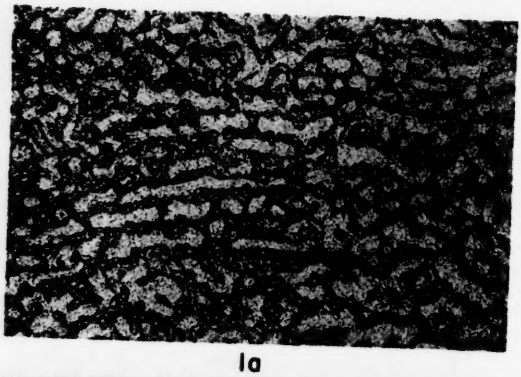
3b



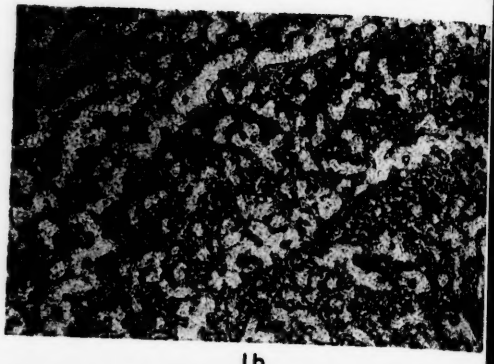
4a



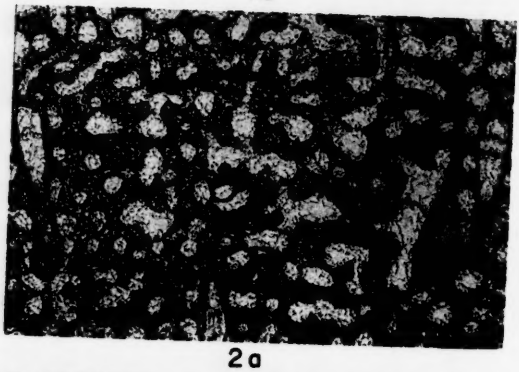
4b



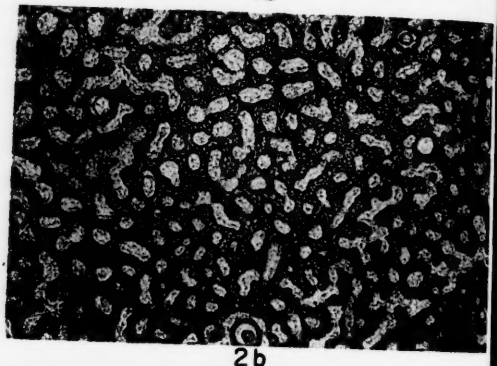
1a



1b

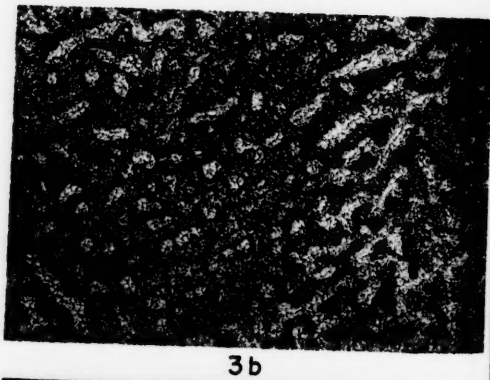


2a



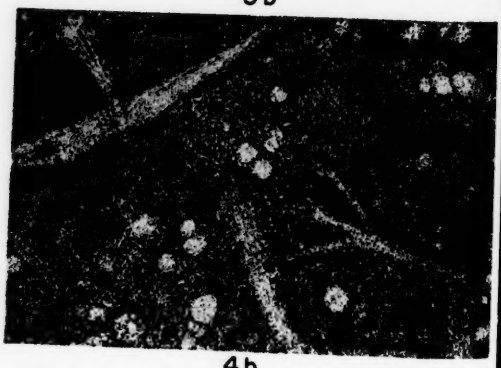
2b

3a



3b

4a



4b

TRUPETOSTROMA WARRENI Parks
Pl. 72, figs. 4a,b

Trupetostroma warreni PARKS, 1936, Univ. Toronto Studies, geol. ser., no. 39, p. 55 (Mid. Dev., Great Slave Lake, Canada); GALLOWAY & ST. JEAN, 1957, Am. Paleontology, Bull., v. 37, no. 162, p. 159; GALLOWAY, 1957, Am. Paleontology, Bull., v. 37, no. 164, p. 439.

Exterior.—Coenosteum massive; surface with mamelons 5 to 7 mm. in diameter and 1 mm. high. Astrorhizae obscure.

Vertical section.—Laminae regular, 7 to 9 in 2 mm., tripartite with light-colored microlamina and lower and upper dense, secondary layers. Pillars spool-shaped, regularly superposed, variable in width, continuous with the secondary layers of the laminae. There are many round or oval vacuoles in the pillars and foramina in the laminae. Galleries regularly superposed, astrorhizal canals scattered, round. Dissepiments scarce.

Tangential section.—The pillars are confluent in the laminae, leaving round galleries, 0.15 to 0.2 mm. in diameter. Small, round vacuoles are abundant in the lower and upper layers of the laminae. Between laminae the pillars are small, round, or oval, giving a very different appearance from the section lengthwise of the laminae.

Occurrence.—A typical specimen was collected by Dan Kralis, Jr. in 1943, from the Devonian, Kee Scarp bioherm of the Fort Creek shale, from Hoosier Ridge, 22 miles down the Mackenzie River from Norman Wells. It seems to be identical with the type designated as "Middle Devonian, Great Slave Lake," by Parks. Indiana University, no. 5480, slide 282–26.

TRUPETOSTROMA IOWAENSE Parks
Pl. 73, figs. 1a,b

Trupetostroma iowaense PARKS, 1936, Univ. Toronto Studies, geol. ser., no. 39, p. 57, pl. 10, figs. 3–6. (Mid. Dev., Cedar Valley formation, Mason City, Iowa).

Exterior.—Coenosteum massive; surface without mamelons but with astrorhizae about 10 mm. in diameter. Latilaminae about 2 mm. thick.

Vertical section.—Laminae in places thick, 0.3, with median light line, mostly indicated by slightly curved tabulae at vaguely concordant levels; in places laminae are vague or missing. Pillars continuous, not merely superposed, and prominent, 0.17 thick, in places interrupted by galleries, in other places 6 to 10 are parallel and contiguous for 1 or 2 mm. The tissue is dense, of a golden color, with feathery fibers tending to radiate around galleries and vacuoles, making dark irregular lines between two adjacent pillars. Galleries oval or elongate horizontally, tending to be superposed between the pillars, in places large, the astrorhizal canals without tabulae. Vacuoles round and common between laminae and between pillars. Dissepiments scarce.

Tangential section.—Pillars broad, up to 0.2 mm., joined and radiating about an astrorhizal center, surrounding irregular galleries and round vacuoles in and outside the astrorhizae. Tissue dense and radially fibrous around the vacuoles and round galleries. Tabulae scarce in the astrorhizal canals.

Comparisons.—Parks' type is from the Middle? Devonian, Cedar Valley formation, with which the Ramparts specimen agrees

---

EXPLANATION OF PLATE 74

All figures ×10

FIGS. *1*—*Ferestromatopora jacquesensis* Galloway, n. sp. *a*, Vertical section; and *b*, oblique tangential section. *Radiastrea* Zone. Holotype, P. U., 83008, slide MV1-14.

2—*Stromatopora* cf. *S. hüpschi* Bargatzky. *a*, Vertical secion; and *b*, tangential section. *Stringocephalus* Beds. P. U., 82710, slide MV1-16.

3—*Stromatopora arcuata* Galloway, n. sp. *a*, Vertical section; and *b*, tangential section. *Stringocephalus* Beds. Holotype, P. U., 83006, slide MV1-17.

4—*Stromatopora* cf. *S. maculata* Lecompte. *a*, Vertical section; and *b*, tangential section lengthwise of a lamina. *Radiastrea* Zone. P. U., 83009, slide MV1-18.

in all respects. The Ramparts specimen also appears to be identical with specimens from the Nora member of the Shell Rock formation from Nora Springs, Iowa, which formation is considered to be Upper Devonian (Cooper, 1942, p. 1780).

Occurrence.—A large fragment, perfectly preserved, from the Middle Devonian, Ramparts formation, *Stringocephalus* Beds, 220 feet above base, near Fort Good Hope, Mackenzie Valley. Collected by A. C. Lenz, 1958, locality L14. Princeton University, no. 82709, slide MV1-9. Fragment, Indiana University, slide 307-81.

TRUPETOSTROMA POROSUM Lecompte
Pl. 73, figs. 2a,b

Trupetostroma porosum LECOMPTE, 1952, Inst. Roy. Sci. Nat. Belgique, Mém. 117, p. 236, pl. 42, fig. 3, pl. 43, fig. 1 (Up. Dev., Lower Frasnian, Belgium).

Exterior.—Coenosteum nodular; surface without mamelons, but with large astrorhizae, 20 mm. in diameter. Latilaminae about 2 mm. thick.

Vertical section.—Laminae thick, 0.15 to 0.2 mm., with light, median line, the laminae much interrupted by small vacuoles, superposed galleries and large, oval astrorhizal canals. In places there are vertical or curved pores, suggestive of *Parallelopora*, but the tissue is compact, not maculate. Pillars strong, more prominent than the laminae, superposed but interrupted by the astrorhizal canals, and having numerous vacuoles. Astrorhizal canals large, round to oval, 0.3 to 0.7 mm. in diameter, many with curved tabulae.

Tangential section.—The pillars are thick and confluent, and composed of dusty tissue, not maculate, with numerous round vacuoles 0.03 to 0.1 mm. in diameter. Some of the vacuoles join others, forming irregular pores, as in the vertical section. Galleries round 0.25 to 0.3 mm. in diameter and also anastomosing. Astrorhizal canals large, long and branching, up to 0.5 mm. in diameter, with scattered, curved diaphragms. The vacuoles, galleries, and canals occupy up to half of the tangential section.

Comparison.—The Mackenzie Valley specimens seem to be typical of the species. There is little to distinguish this species from *Trupetostroma tenuilineatum* Lecompte and *T. laceratum* Lecompte, and from *Gerronostroma schelonense* Yavorsky (1957, pl. 5, figs. 6,7). Similar species range from the Givetian into the Frasnian.

Occurrence.—Post-*Stringocephalus* Beds, possibly Upper Devonian, 240–345 feet above base, near Fort Good Hope, Lenz locality L14. Collected by A. C. Lenz, 1958. Princeton University, no. 82708, slide MV1-10.

TRUPETOSTROMA MAILLIEUXI Lecompte
Pl. 73, figs. 3a,b

Trupetostroma maillieuxi LECOMPTE, 1951, Inst. Roy. Sci. Nat. Belgique, Mém. 116, p. 237, pl. 43, figs. 2,3 (Up. Dev., Lower Frasnian, Belgium).

This species is like *Trupetostroma porosum*, but the astrorhizae and astrorhizal canals are smaller and do not dominate the sections as they do in *T. porosum*. The vacuoles are abundant, round, small and variable in size, but they do not overwhelm other structures as the maculae do in *Parallelopora*.

Occurrence.—*Stringocephalus* Beds, Moon Lake, 20 miles north of Norman Wells, Northwest Territories, collected by A. C. Lenz, 1958, locality K124. Princeton University, no. 83019, slide MV1-11.

TRUPETOSTROMA COALESCENS Galloway & St. Jean
Pl. 73, figs. 4a,b

Trupetostroma coalescens GALLOWAY & ST. JEAN, 1957, Am. Paleontology, Bull., v. 37, no. 162, p. 152, pl. 12, fig. 5 (Mid. Dev., Logansport ls., Logansport, Indiana).

Exterior.—Coenosteum massive to nodular; surface with low mamelons, 3 to 4 mm. in diameter and 8 to 10 mm. apart. Astrorhizae obscure, even on polished surfaces. Latilaminae about 3 mm. thick.

Vertical section.—Laminae thick, 6 to 8 in 2 mm.; pillars thicker than the laminae, 6 or 8 in 2 mm., many coalescing, continuous, composed of compact, fibrous tissue which converges upward toward the center of the pillars. Where the pillars touch, there is darker, irregular tissue. Galleries small, low, thin, superposed between the pillars. Vacuoles small, obscure. Astrorhizal canals small, round, larger than the galleries. About 90 percent of the section is tissue.

Tangential section.—Laminae can scarcely be distinguished, the section consisting mostly of coalescent pillars, but in places the galleries appear as round or anastomosing openings surrounded by pillars. Small astrorhizal canals, 0.1 mm. wide, occur. Small vacuoles, 0.03 mm. in diameter, are common in the pillar tissue.

Comparisons.—This species is characterized by the large amount of tissue compared to galleries, astrorhizal canals and vacuoles, the opposite of *T. porosum*. The Mackenzie Valley specimens seem to agree in every way with the Logansport type. Similar species with the same fibrous kind of tissue occur in the Middle Devonian of Manitoba and Iowa.

Occurrence.—One specimen from the *Stringocephalus* Beds, 200 to 220 feet above the base of the Ramparts formation, near Fort Good Hope, Lenz locality L14, no. 83002, slide MV1-12. One specimen from the *Stringocephalus* Beds, Moon Lake, 20 miles north of Norman Wells, Lenz locality K122, No. 82711, slide MV1-13. One doubtful specimen from the Pre-*Stringocephalus* Beds, *Radiastrea arachne* Zone, Lac Jacques, north of Norman Wells, Mackenzie Valley, Lenz locality S47, no. 83008, attached to *Ferestromatopora jacquesensis* n. sp. All in Princeton University.

Genus FERESTROMATOPORA Yavorsky, 1955
Type: *F. krupennikovi* Yavorsky, 1955
(Mid. Dev., Kuznetz Basin, Russia);
Galloway, 1957.

Coenosteum massive; tissue maculate and amalgamated; laminae well formed; pillars indefinite, merely upward growths of the laminae, not superposed; pseudozooidal tubes absent, but with an occasional foramen between superposed galleries. Differs from *Stromatopora* in having laminae and no pseudozooidal tubes.

FERESTROMATOPORA JACQUESENSIS
Galloway, n. sp.
Pl. 74, figs. 1a,b

Exterior.—Coenosteum a nodule 3.5 cm. in diameter, made mostly of the *Ferestromatopora* overgrown by *Trupetostroma*. Surface not shown, but there is no evidence of mamelon columns in the vertical section. Latilaminae about 2 mm. thick.

Vertical section.—Laminae well formed but variable in thickness, 0.1 to 0.15 mm., and irregularly undulating, 7 in 2 mm. Pillars irregularly formed and sporadic, vertical or oblique, only a few reaching the laminae above, formed of the same tissue as the laminae. Tissue coarsely maculate. Maculae variable in size, 0.04 to 0.09 mm., not arranged either horizontally or vertically, mostly with clear lumina. Galleries round where there happen to be two pillars close together, mostly elongate, up to 3 mm. long, variable in shape but in general horizontally arranged, not in tiers, but there is an occasional foramen between a gallery and a superposed one. Astrorhizae small and obscure, some with small vertical tube, but not forming astrorhizal or mamelon columns. Dissepiments rare; astrorhizal canals with an occasional tabula. Pseudozooidal tubes absent.

Tangential section.—The laminae make irregular bands of coarsely maculate tissue, between which the pillars are irregular in size and shape, some joined. Galleries very irregular in shape and size mostly joining others. Astrorhizae rare, small, poorly formed. Dissepiments very rare.

Comparisons.—This species is a good *Ferestromatopora*, lacking the pseudozooidal tubes of *Stromatopora*. The coarse maculae and long galleries distinguish it from all other known species of the genus.

Occurrence.—One specimen from the Middle Devonian, *Radiastrea arachne* Zone, Lac Jacques, north of Norman Wells, Northwest Territories. Collected by A. C. Lenz, 1958, locality S47. Princeton University, no. 83008, slides MV1-14,15. Indiana University, slide 307-82.

Genus STROMATOPORA Goldfuss, 1826
Type: *S. concentrica* Goldfuss, 1826
(Mid. Dev., Gerolstein, Germany);
Galloway, 1957.

Coenosteum massive; tissue maculate and amalgamated; laminae and pillars indefinite, but vertical, tabulate tubes dominant.

STROMATOPORA cf. S. HÜPSCHI Bargatzky
Pl. 74, figs. 2a,b

Caunopora hüpschii BARGATZKY, 1881, Verhandl. naturhist. Vereins Preuss. Rheinlande Westfalens, v. 38, p. 290 (Mid. Dev., Steinbruch, Germany).

Stromatopora hüpschii NICHOLSON, 1886b, Palaeontological Soc. London, v. 39, pl. 10, figs. 8,9;—, 1891, v. 44, p. 176; LECOMPTE, 1952, Inst. Roy. Sci. Nat. Belgique., Mém. 117, p. 268, pl. 52, figs. 2,3a,2b; YAVORSKI, 1955, Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister, Geol. i Ochrany Nedr., new ser., v. 8, p. 106, pl. 56, figs. 3,4.

Exterior.—Coenosteum massive, fragmentary; surface nearly smooth, with indications of low mamelons and imperfect astorhizae. Latilaminae obscure, 3 to 5 mm. thick.

Vertical section.—The laminae are thick, 0.15 to 0.2 mm., but developed only in places, better seen with the hand lens than with the microscope, composed of maculate tissue. The maculae are large and conspicuous, dark rings 0.03–0.06 mm. in diameter, with large, round lumina. In a few places, the maculae are in horizontal lines, making microlaminae. The pillars are amalgamated with the laminae, composed of precisely the same kind of maculate tissue, and are in part oblique, in part only one interlaminae space in length, and in part continuous, rather than merely superposed, for a distance of 2 to 6 interlaminar spaces. The pillars are of the same general thickness as the laminae, 0.15 to 0.2 mm. The galleries are mostly round, some elongate horizontally, many joined, forming vermicular patterns, and many superposed with maculate tissue or with upwardly curved tabulae between. There are a few definite pseudozooidal tubes. There are many vertical tubes of *Syringopora* (caunopore tubes) 0.3 to 0.4 mm. in diameter and some horizontal stolons of smaller diameter connecting the corollile s. The *Syringopora* tubes have thin, dark walls and some have infundibular tabulae. Astrorhizal tubes are difficultly distinguished from galleries, mainly being larger. Dissepiments scarce.

Tangential section.—The laminae, where observable, are broad bands made of uniformly maculate tissue, containing many small, round galleries or pseudozooidal tubes. Between laminae the tissue is maculate, in anastomosing bands, 0.15 to 0.2 mm. thick, which enclose vacuities of various shapes and sizes. The galleries are round, oval and vermicular, 0.05 to 0.18 in diameter, the smallest round ones being the pseudozooidal tubes. Astrorhizal canals are long, sparsely branched, 0.2 to 0.3 mm. in diameter, rarely making radial patterns. Dissipiment rare in the galleries, and tabulae rare in the canals. Round tubes, 0.3 to 0.4 mm. in diameter, a species of *Syringopora*, are abundant, as is usual for the species. It is interesting to note that the *Syringopora* is always surrounded by tissue which is not damaged by the foreign object, and that it is never in the galleries or astrorhizal canals. The *Syringopora* is therefore a symbiont rather than a parasite.

Comparisons.—The Mackenzie Valley specimen has fewer pseudozooidal tubes than is shown by both Nicholson's and Lecompte's figures, but it seems to be identical with Yavorsky's figures of the species. *Syringopora* is commonly associated with this species. There are no round pillars, as in *Syringostroma*, *Taleastroma*, *Hermatostroma*, or *Parallelopora;* but there are pseudozooidal tubes, separating it from *Ferestromatopora;* pillars are merely the tissue separating the galleries.

Occurrence.—One fragment from the Middle Devonian, Ramparts formation, *Stringocephalus* Beds, Greenhorn Creek, Moon Lake, 20 miles north of Norman Wells, Northwest Territories. Collected by A. C. Lenz, 1958, locality K124. Princeton University, no. 82710, slide MV1-16. Indiana University, slide 307-83.

STROMATOPORA ARCUATA Galloway, n. sp.
Pl. 74, figs. 3a,b

Exterior.—Coenosteum an undulating, thick plate. Surface smooth except where there are slightly elevated astrorhizae, 5 mm. in diameter and 10 mm. apart. Latilaminae 2 to 3 mm. thick, along which the coenosteum freely splits.

Vertical section.—Laminae thick, 0.23 to 0.3 mm., about 6 in 2 mm., fairly continuous, with many foramina, composed of large maculae in 2 to 4 horizontal rows and light-colored accessory tissue. Pillars short, rarely superposed, spool-shaped, continuous with the laminae, about 6 in 2 mm. Galleries mostly with vaulted ceiling and flat floor, round, or elongate, 0.3 mm. in height, in part superposed, making occasional pseudozooidal tubes, with pillars between, the length partly depending on the verticality of the section. Maculae large, light colored,

0.04 to 0.06 mm. in diameter, with dark, smaller, fuzzy maculae between, many cut in the center showing a light lumen, partly in vertical lines, but not as much as in *Parallelopora*. Astrorhizal canals round, slightly larger than the galleries, but none showing a vertical tube. Dissepiments absent.

Tangential section.—In the laminae the tissue occupies nearly all of the area; it is coarsely and conspicuously maculate. The galleries are round and irregular in shape, the pseudozooidal tubes round and smaller than the galleries, both surrounded by a darker ring of maculate tissue. Between laminae, both galleries and pillars make a pattern of anastomosing figures, similar to that in *Stromatopora hüpschi*, but without *Syringopora* tubes. There are no separate, round pillars. Astrorhizae are typical, but without central tube, with small canals without tabulae.

Comparisons.—This species has laminae, which are not apparent in many species of *Stromatopora*, and the dominant laminae ally it with *Ferestromatopora*. It takes its name from the arcuate ceilings of the galleries. It resembles several species named by Yavorsky from the Middle Devonian of Russia (1955, pls. 42–57), but none seems to be identical.

Occurrence.—One specimen from the Middle Devonian, Ramparts formation, *Stringocephalus* Beds?, Manuel Lake, northeast of Fort Good Hope, Northwest Territories. Collected by A. C. Lenz, 1958, locality K101. Princeton University, no. 83006, slide MV1-17. Indiana University, slide 307-84.

STROMATOPORA cf. S. MACULATA Lecompte
Pl. 74, figs. 4a,b

Stromatopora maculata LECOMPTE, Inst. Roy. Sci. Nat. Belgique, Mém. 117, 1952, p. 283 (Up. Dev., Lower Frasnian, Belgium).

Exterior.—Coenosteum nodular; surface smooth, with astrorhizal canals. Latilaminae about 2 mm. thick.

Vertical section.—The laminae are thin but definite, about 7 in 2 mm., composed of a line of large maculae, with much coarsely maculate tissue above and below. Pillars are merely the tissue between galleries, which are round, and superposed in places, making pseudozooidal tubes. Astrorhizal canals large. Dissepiments lacking.

Tangential section.—The section is mostly maculate tissue, with round galleries and long astrorhizal canals.

Comparison.—Our specimen is somewhat leached, but agrees fairly well with Lecompte's figures. It occurs also in the Givetian of Belgium.

Occurrence.—One specimen from the "Ramparts" formation, *Radiastrea arachne* Zone, Carcajou Lake, Mackenzie Mountains, Northwest Territories. Collected by A. C. Lenz, 1958, locality K72B. Princeton University, no. 83009, slide MV1-18.

STROMATOPORA PLANULATA (Hall & Whitfield)?
Pl. 75, figs. 1a,b

Caunopora planulata HALL & WHITFIELD, 1873, 23rd. Ann. Rept. Reg. Univ. State of New York, p. 228, pl. 9, fig. 2 (Up. Dev., Cerro Gordo mem. of Lime Creek fm., Hackberry, Iowa); PARKS, 1936, Univ. Toronto studies, geol. ser., no. 39, p. 62; LECOMPTE, Inst. Roy. Sci. Nat. Belgique, Mém. 117, 1952, p. 286, pl. 50, figs. 1,2 (from Nicholson's slides).

Exterior.—Surface undulating but nearly smooth, without mamelons, but with typical astrorhizae 5 mm. in diameter and 8 to 10 mm. apart. Latilaminae 2 to 3 mm. thick.

Vertical section.—Laminae regular under the hand lens, but under the microscope the laminae are discontinuous and composed of about two horizontal lines of large maculae with much maculate thickening tissue above and below, about 6 laminae in 2 mm. Pillars are not well formed, being mostly the maculate tissue between galleries, generally not superposed. Galleries mostly round and small, 0.15 mm. in diameter, in horizontal lines or in part superposed, making short pseudozooidal tubes. Astrorhizal canals are twice as thick as the galleries, are horizontal or oblique, some with convex tabulae. Both galleries and astrorhizal canals are surrounded by a dark ring of more compact tissue, a feature seen in few other species of stromatoporoids. The maculae are very large and conspicuous, 0.06 mm. in diameter, with a central clear spot. Dissepiments are absent excepting between superposed galleries.

Tangential section.—The ground mass is coarsely maculate tissue in which there are

numerous galleries, mostly round, and each surrounded by a ring of dark, more compact tissue. The astrorhizae are well formed, with branching, radial canals, 0.12 to 0.15 mm. in diameter, with an occasional tabula. There are no pillars, only tissue between galleries and canals.

Comparisons.—What Hall & Whitfield's species is has not been determined. Parks (1936, p. 62), has a poorly preserved topotype which he designed "unreliable," and assigned the form to *Trupetostroma*. The writer has studied Parks' slides and finds them indeterminate. Lecompte (1952, p. 286) figured Nicholson's slides from a specimen from Rockford, Iowa, eight miles south of Hackberry, the type locality. The Norman Wells specimen resembles the figures of Lecompte (pl. 50, figs. 1,2), which may or may not be Hall & Whitfield's species; it has more pseudozooidal tubes and therefore the semblance of pillars between is more marked than in our specimen. The vertical elements are less pronounced than in *Stromatopora cooperi* Lecompte (1952, p. 285). The present form is a typical *Stromatopora*, having maculate tissue, obsolescent laminae, no real pillars, but with vertical, pseudozooidal tubes, made of superposed galleries, It does not have maculae in tiers, as does *Parallelopora*.

Occurrence.—One specimen from the Devonian, Fort Creek shale, Kee Scarp member, Norman Wells, Northwest Territories. Collected by A. C. Lenz, 1958, locality L1. Princeton University, no. 83016, slide MV1-19. Indiana University, slide 307-85.

Genus TALEASTROMA Galloway, 1957
Type: *Stromatopora cumingsi* Galloway & St. Jean, 1957; Galloway, 1957.

Coenosteum massive; tissue maculate; laminae regular; pillars long, thin, composed of compact tissue with maculate borders. Differs from *Trupetostroma* in the maculate tissue.

TALEASTROMA LENZI Galloway, n. sp.
Pl. 75, figs. 2a,b

Exterior.—Coenosteum nodular; surface even, with neither mamelons nor astrorhizae. Latilaminae 2 to 3 mm. thick.

Vertical section.—Laminae even, 8 in 2 mm., consisting of one or two dark, coarsely maculate microlaminae, with maculate secondary tissue below, above and between microlaminae. Pillars long, superposed, spool-shaped and irregular in width, about 6 in 2 mm., composed of compact tissue with coarse macule irregularly arranged on the edges of the pillars. Galleries tend to be round, wider than the laminae. Astrorhizae absent. Dissepiments scarce, common in scattered places.

Tangential section.—The laminae appear as broad, maculate bands. The pillars tend to be round between laminae, many joining, making an indefinite pattern of laminae, pillars and irregular galleries. Astrorhizae absent.

Comparisons.—This species differs from *Taleastroma pachytextum* (Lecompte), in the smaller pillars, and from *T. cumingsi* in lacking astrorhizae.

Occurrence.—One good specimen from the *Radiastrea arachne* Zone of the Ramparts formation, 230–265 feet above base, East Mountain, 20 miles northwest of Norman Wells, Northwest Territories. Collected by A. C. Lenz, 1958, locality L11. Princeton University, no. 83004, slide MV1-20. Indiana University, fragment and slide 307-86.

TALEASTROMA CONICOMAMILLATA
(Galloway & St. Jean)
Pl. 75, figs. 3a,b

Stromatopora conicomamillata GALLOWAY & ST. JEAN, 1957, Am. Paleontology, Bull., v. 37, no. 162, p. 184 (Mid. Dev., Logansport ls., Indiana).

Exterior.—Coenosteum attached to a coral, *Coenites;* surface undulating, with small mamelons, 1 to 2 mm. in diameter and 0.5 mm. high and 2 to 4 mm. apart from the summits, each with a minute, well-formed astrorhizae with 8 to 10 radiating canals; some canals join those of adjacent astrorhizae. On and between the mamelons the surface is minutely but conspicuously papillate, the papillae joining between astrorhizal canals.

Vertical section.—Laminae thin, discontinuous, composed of a few microlaminae and thickening tissue, 7 to 8 laminae in 2 mm. Pillars small, long, about 8 in 2 mm., composed of clear tissue with maculae on the outside. Galleries low, superposed between pillars, making narrow, tabulate pseudo-

zooidal tubes. Astrorhizae small, but larger than the galleries, and round, with tabulae. Dissepiments scarce.

Tangential section.—The laminae and pillars are fused. Laminae are broad bands of maculate tissue, with round, clear pillars, 0.07 to 0.1 mm. in diameter, with an outside ring of dark maculae. Galleries and pseudozooidal tubes are round, 0.1 to 0.2 mm. in diameter. Astrorhizae have small, branching canals but no vertical tube.

Comparison.—This is splendidly preserved, the surface better than in the type material, with which it agrees in all details. The pillars are smaller than in *Taleastroma cumingsi* and *T. pachytextum.*

Occurrence.—A single specimen occurs in the *Rensselandia* Beds of the Ramparts formation, 120 feet above the base, near Fort Good Hope, Mackenzie River, Northwest Territories. Collected by A. C. Lenz, 1958, locality L14. Princeton University, no. 82704, slide MV1-21.

TALEASTROMA VITREUM Galloway, n. sp.
Pl. 75, fig. 4a,b; Pl. 76, figs. 1a,b

Exterior.—Coenosteum a small head, 40 mm. in diameter; surface overgrown by a *Parallelopora*, but it had mamelons about 4 mm. in diameter and astrorhizae of the same size. Latilaminae about 3 mm. thick.

Vertical section.—Laminae well formed, 6 in 2 mm., 0.12 to 0.17 mm. thick, undulating, composed of clear homogeneous tissue which has dark large maculae, 0.05 to 0.09 mm. in diameter on each side, but not making straight rows. Pillars strong, variable in size, 0.1 to 0.34 mm. in diameter, about 5 in 2 mm., continuous and amalgamated with the laminae and composed of the same clear, glassy material, with large maculae irregularly arranged on the borders. Galleries round, or elongate, superposed, with foramina between, in places forming pseudozooidal tubes. Astrorhizae with canals larger than the galleries, forming astrorhizal columns, but without well-formed, vertical astrorhizal tubes. Astrorhizal canals with a few curved tabulae. Dissepiments very rare. The name *vitreum* refers to the glassy appearance of the cores of the laminae and pillars. The glassy material is minutely dusty.

Tangential section.—The laminae and pillars are amalgamated, enclosing round and anastomosing galleries and small but well-formed astrorhizae. Pillars are round, with rough edges, caused by dark maculae and dark tissue, mostly 0.15 to 0.23 mm. in diameter, many joining with the laminae and with each other.

Comparisons.—This species is a typical *Taleastroma*, with its continuous pillars formed of clear tissue. It differs from *T. cumingsi* in the larger pillars, from *T. pachytextum* (Lecompte) in the smaller pillars, and from all other species of the genus, so far known, by the clear or vitreous appearance of the laminae as well as of the pillars. It has mamelons like *T. magnimamillatum* (G. & St. J.), but the pillars are larger and the laminae are not made of microlaminae, but of clear tissue.

Occurrence.—One good specimen from the Middle Devonian, Ramparts formation. *Rensselandia* Beds, 120 feet above the base, near Fort Good Hope, Northwest Territories, collected by A. C. Lenz, 1958, locality L14. Princeton University, no. 83005, slides MV1-22, 23, 24, 25. Indiana University, fragment and slides 307-87, 88, 89.

Genus SYRINGOSTROMA Nicholson, 1875
Type: *S. densum* Nicholson, 1875; Galloway, 1957

Coenosteum massive; laminae regular, thick; pillars large, regularly superposed or continuous; tissue of laminae and pillars maculate and fused. Maculae not vertically superposed, as in *Parallelopora.*

SYRINGOSTROMA SANDUSKYENSE
Galloway & St. Jean
Pl. 76, figs. 2a,b; 3a,b

Syringostroma sanduskyense GALLOWAY & ST. JEAN, 1957, Am. Paleontology, Bull., v. 37, no. 162, p. 190, pl. 16, figs. 4a,b (Mid. Dev., Sandusky, Ohio).

Exterior.—Coenosteum massive; surface without mamelons but with inconspicuous astrorhizae. Latilaminae 5 to 10 mm. thick.

Vertical section.—Laminae regular, thick, 0.12 mm., consisting of 1 to 3 maculate microlaminae, with maculate tissue between, above and below, 7 to 8 in 2 mm. Pillars spool-shaped, regularly superposed, thicker than the laminae, coarsely maculate,

but the maculae are not in vertical tiers as in *Parallelopora*. Galleries round to elongate horizontally, about as thick as the laminae, regularly superposed between the pillars. Astrorhizal canals round, larger than the galleries. Dissepiments scarce. There are occasional foramina between superposed galleries. There are no mamelon columns.

Tangential section.—Laminae and pillars coarsely maculate. Pillars round between the laminae, 0.15 to 0.2 mm. in diameter, elongate and joining at the laminae. Astrorhizae conspicuous, with many small canals, but without central tube; tabulae nearly absent.

Comparisons.—The Mackenzie Valley specimen has thinner laminae, smaller pillars and larger maculae than the Sandusky type, but agrees in all other respects; it might be a variety of that species.

Occurrence.—One large specimen from the Middle Ramparts formation, 183 to 200 feet above the base, *Stringocephalus* Beds, near Fort Good Hope, no. 82702, slide MV2-1, and one from the *Radiastrea arachne* Zone, 230 to 265 feet above the base of the "Ramparts" formation, about 20 miles northeast of Norman Wells, Northwest Territories, no. 82703, slides MV2-2,3. Collected by A. C. Lenz, 1958, localities L14 and L11. Princeton University. Indiana University, slides 307-90,91,92.

Genus PARALLELOPORA Bargatzky, 1881

Type: *P. ostiolate* Bargatzky, 1881; Nicholson, 1891; Lecompte, 1952; Galloway & St. Jean, 1957; Galloway, 1957.

Coenosteum massive; laminae composed of microlaminae; pillars large, separate or confluent, continuous or superposed, composed of large, superposed maculae, characteristic of the genus, forming tubules, and smaller dark maculae, forming rods; galleries superposed (the parallel pores of Bargatzky), not confined to this genus; astrorhizae large.

PARALLELOPORA OSTIOLATE Bargatzky

Pl. 76, figs. 4a,b

Parallelopora ostiolate BARGATZKY, 1881, Verhandl. naturhist. Vereins Preuss. Rheinlande Westfalens, v. 38, p. 292 (Up. Mid. Dev., Büchel, Germany); NICHOLSON, 1886b, Palaeontological Soc. London, v. 39, p. 95; ——, 1891, v. 44; LECOMPTE, 1952, Inst. Roy. Sci. Nat. Belgique, Mém. 117, p. 293, pl. 51, fig. 3; GALLOWAY & ST. JEAN, Am. Paleontology, Bull., v. 37, no. 162, p. 207.

Exterior.—Coenosteum massive; surface undulating, with astrorhizae, 5 to 8 mm. in diameter; mamelons not apparent; latilaminae about 5 mm. thick.

Vertical section.—Under the hand lens the laminae are thick, 4 in 2 mm., and the pillars thick and continuous, 6 in 2 mm.

Under the microscope the thick laminae, about 0.25 mm. thick, are less apparent, composed of darker, thin microlaminae. Each thick lamina is made of 3 or 4 microlaminae and secondary tissue. There are 12 to 14 thin microlaminae in 2 mm., each composed of dark maculae. Laminae and galleries are in general parallel arrangement. The galleries are small, round or oval horizontally, and superposed. The pillars are thick, 0.1 to 0.18 mm. thick, and continous, 5 or 6 in 2 mm., and composed of 2 to 4 vertical tiers of very large, light-colored maculae, making tabulate tubules, the tubules separated by vertical tiers of dark, smaller maculae, making a semblance of "rods," as noted by Nicholson (1891, p. 193). Astrorhizal tubes, larger than galleries,

---

EXPLANATION OF PLATE 75

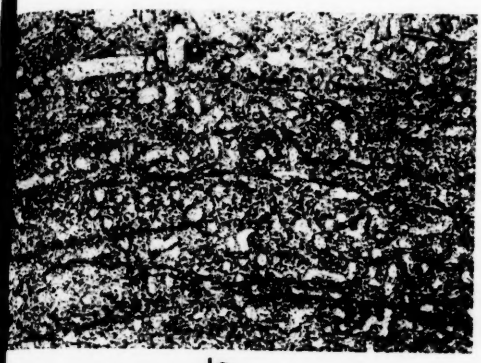
All figures ×10

FIGS. *1*—*Stromatopora planulata* (Hall & Whitfield)? *a*, Vertical section, the oblique, dark lines are fractures; and *b*, tangential section. Kee Scarp Reef. P. U., 83016, slide MV1-19.

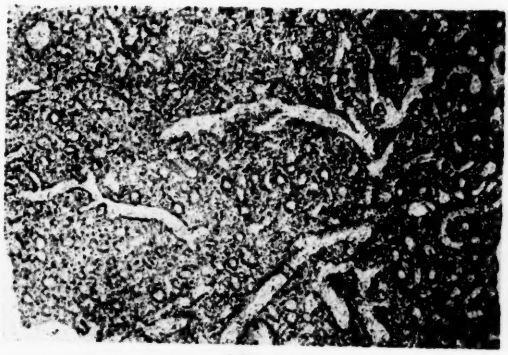
2—*Taleastroma lenzi* Galloway, n. sp. *a*, Vertical section; and *b*, oblique tangential section. *Radiastrea* Zone. P. U., 83004, slide MV1-20.

3—*Taleastroma conicomamillatum* (Galloway & St. Jean). *a*, Vertical section; and *b*, tangential section. *Rensselandia* Beds. P. U., 82704, slide MV1-21.

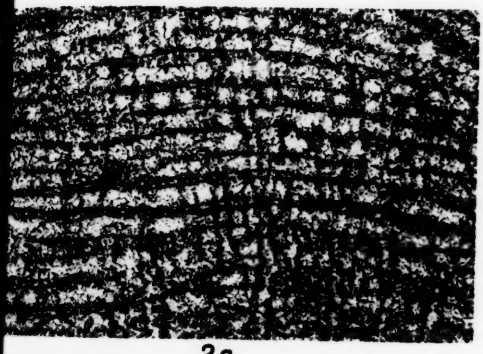
4—*Taleastroma vitreum* Galloway, n. sp. *a*, Vertical section, slide MV1-23; and *b*, tangential section; *Rensselandia* Beds. Holotype, P. U., 83005. Indiana University, slides 307-87,88, 89.



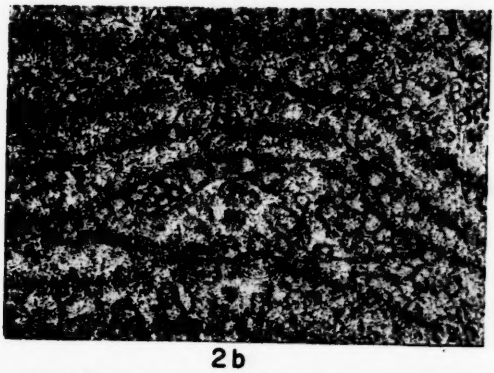
1a



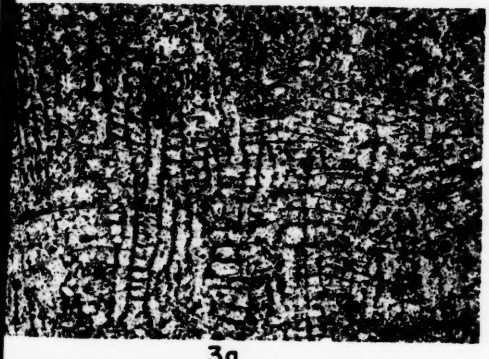
1b



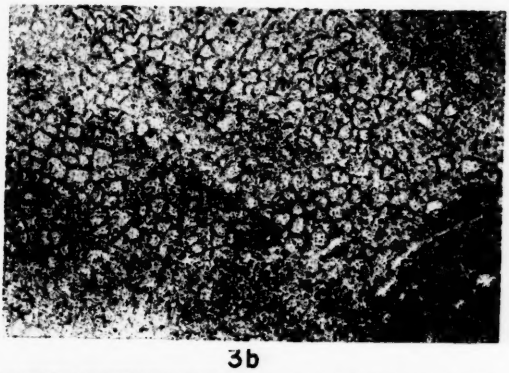
2a



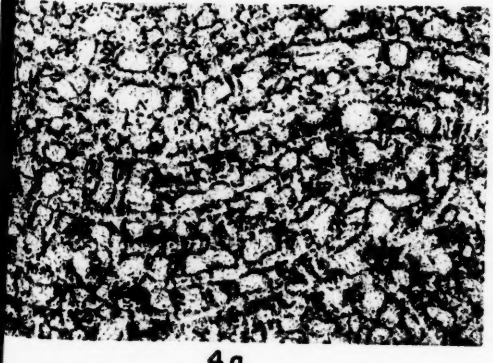
2b



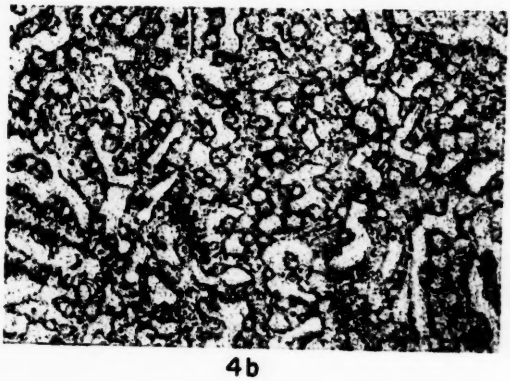
3a



3b



4a



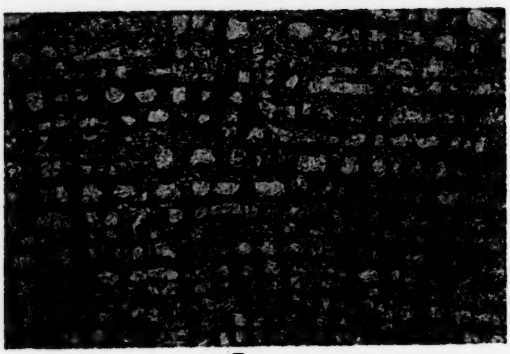
4b

1a

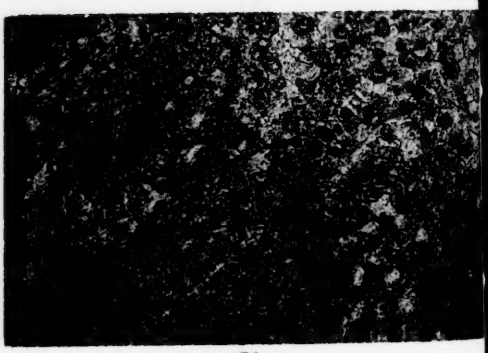
1b

2a

2b

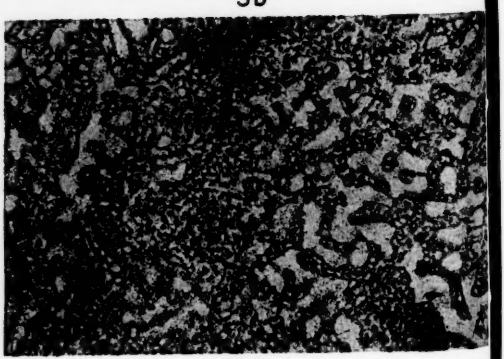


3a



3b

4a



4b

0.4 mm. in diameter, are scattered throughout the section; Lecompte's figure (1952, pl. 51, fig. 3) shows superposed astrorhizae. Dissepiments are rare or missing. Pseudozooidal tubes, other than the superposed tiers of chambers, are not recognized.

Tangential section.—The laminae are composed of coarsely maculate tissue, with round and irregular galleries and astrorhizal canals. The maculae are large, 0.04 to 0.06 mm. in diameter, mostly dark but many are cut through the center, showing the light lumina. Between laminae, where the section cuts the galleries, the pillars are in part confluent, 0.17 to 0.23 mm. thick, separating the round to irregular galleries. In addition to the dark maculae mentioned, there are abundant maculae of enormous size, 0.07 to 0.12 mm. in diameter. Astrorhizal canals are large and irregular.

Comparisons.—The specimen is apparently identical in all respects with Bargatzky's type. The maculae are larger and in more conspicuous vertical tiers than in any other species of the genus. The large maculae in vertical tiers are the diagnostic character of the genus, rather than the superposed galleries. Bargatzky (1881, p. 292) named the species *P. ostiolata* because of the vertical tubes in the axes of the astrorhizae.

Occurrence.—One small specimen from the *Stringocephalus* Beds of the Ramparts formation, Middle Devonian, Moon Lake, 20 miles north of Norman Wells, Northwest Territories. Collected by A. C. Lenz, 1958, locality K122. Princeton University, no. 83001, slide MV2-4. Indiana University, slide 307-93.

PARALLELOPORA PELLUCIDA (Yavorsky)
Pl. 76, figs. 1a,b; Pl. 77, figs. 1a,b

Stromatopora pellucida YAVORSKY, 1955, Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister. Geol. i Ochrany Nedr., new ser., v. 8, p. 91, pl. 39, fig. 7; pl. 48, figs. 5,6 (Mid. Dev., Russia).

Exterior.—Coenosteum attached to an unweathered specimen of *Taleastroma vitreum*. Surface obscure, but with mamelons about 5 mm. in diameter, each with a small astrorhiza.

Vertical section.—The *Parallelopora* is attached to a *Taleastroma* with very different structure, yet the surface of attachment is irregular and obscure, since there is no epithera nor worn surface. Laminae regular and of variable thickness, 6 or 7 in 2 mm., gently curving into mamelon axes, consisting of one dark microlamina with coarsely maculate tissue above and below (Yavorsky's figure), or of two or three dark microlaminae with coarsely maculate tissue between (our specimen). Pillars thick, spool-shaped, regularly superposed, about 5 in 2 mm., consisting of 1 to 3 tiers of coarse maculae, but not making tubules and rods, as in *P. ostiolata*. Galleries mostly round and superposed between the pillars, making tabulate pseudozooidal tubes, some elongate or lobate horizontally. Astrorhizal canals round or elongate, larger than the galleries, with curved tabulae, situated in the mamelon axes. Dissepiments generally few, in places many. Maculae very large, 0.06 to 0.09 mm. in diameter.

Tangential section.—Sections which cut the microlaminae show a variously maculate

---

EXPLANATION OF PLATE 76

All figures ×10

FIGS. *1*—*Taleastroma vitreum* Galloway, n. sp. *a*, Vertical section, overgrown by *Parallelopora pellucida* (Yavorsky), slide MV1-22; and *b*, tangential section of the junction (irregular line) of *Parallelopora pellucida* (Yavorsky), darker tissue, on *Taleastroma vitreum* Galloway, n. sp., lighter tissue. MV1-25. *Rensselandia* Beds. P. U., 83005.

2—*Syringostroma sanduskyense* Galloway & St. Jean. *a*, Vertical section; and *b*, tangential section, mamelon and astrorhiza at left, lamina across the middle, galleries and pillars at right, all tissue corsely maculate. *Stringocephalus* Beds. P. U., 82702, slide MV2-1.

3—*Syringostroma sanduskyense* Galloway & St. Jean. *a*. Vertial section; and *b*, tangential section. *Radiastrea arachne* Zone. P. U., 82703, slides MV2-2,3.

4—*Parallelopora ostiolata* Bargatzky. *a*, Slightly oblique vertical section; and *b*, tangential section. *Strinogcephalus* Beds. P. U., 83001, slide MV2-4.

area with some round galleries. Where the section cuts between the laminae, the pillars are confluent and surround the round and irregular galleries. The pillars are composed of very large maculae, 0.08 to 0.13 mm. in diameter, and dark, finely granular material. The pillars are not round, as in *Syringostroma*. Astrorhizae are large, but only irregular canals show in the section.

Comparisons.—The vertical sections are very similar to Yavorsky's figures, differing only in having 2 or 3 microlaminae to a lamina instead of one. The maculae in vertical section are large but not conspicuously in vertical files, as is required for the genus *Parallelopora*. The tangential secion is scarcely distinguishable from that of *Parallelopora ostiolata*, hence the species is placed in *Parallelopora*.

The *Parallelopora* is attached to *Taleastroma*, which has light-colored laminae with maculae above and below, and also has the thin, light-colored, compact pillars with borders of dark maculae. The lack of definite demarcation between the two genera tends to give the impression that the specimen is only one species, but the great difference between the two genera would seem to rule out the difference being due to preservation, rather than different structure.

Occurrence.—One specimen from the Middle Devonian, *Rensselandia* Beds, Ramparts formation, 120 feet above base, near Fort Good Hope, Northwest Territories. Collected by A. C. Lenz, 1958, locality L14. Princeton University, no. 83005, slides MV1-22,23,24. Indiana University, fragment and slides 307-87,88,89.

Genus CLATHROCOILONA Yavorsky, 1931
Type: *C. abeona* Yavorsky, 1931; Galloway, 1957.

Coenosteum massive; laminae with clear median layer; pillars short, only incidentally superposed; tissue maculate.

CLATHROCOILONA ABEONA Yavorsky
Pl. 77, figs. 2a,b

Clathrocoilona abeona YAVORSKY, 1931, Bull. United Geol. and Prosp. Service, U.S.S.R., v. 50, fasc. 94, p. 1407, pl. 1, figs. 9–11; pl. 2, figs. 1,2,2a (Mid. Dev., Kuznetsk Basin, Russia); GALLOWAY, 1957, Am. Paleontology, Bull., v. 37, no. 164, p. 451, pl. 35, figs. 8.

Exterior.—Coenosteum nodular; intergrown with tubulose canals; surface undulating, but without regular mamelons.

Vertical section.—The laminae, 6 or 7 mm., are thick, 0.15 to 0.2 mm., tripartite, with thin, clear median line and lower and upper thicker, granular and maculate layers. Pillars 6 or 8 in 2 mm., short, rarely superposed, spool-shaped, made of the same granular and maculate tissue as the outer layers of the laminae and continuous with them. Galleries round, oval and irregular, tending to be higher than wide. Astrorhizal tubes larger than the galleries, and indefinite. Dissepiments scarce or absent. There are occasional foramina through the laminae, but no pseudozooidal tubes.

Tangential section.—The section is so confused with the tubular parasites that it offers little information.

Comparison.—*Clathrocoilona abeona* has thinner laminae and pillars and larger galleries than *C. restricta* G. & St. J. It seems to be a typical example of the Russian species.

Occurrence.—One incomplete specimen from the Kee Scarp member of the Fort Creek shale, Middle or Upper Devonian, Norman Wells, Northwest Territories, Canada. Collected by A. C. Lenz, 1958, locality L1. Princeton University, no. 83015, slides MV2-5,6.

CLATHROCOILONA RESTRICTA
Galloway & St. Jean
Pl. 77, figs. 3a,b

Clathrocoilona restricta GALLOWAY & ST. JEAN, 1957, Am. Paleontology, Bull., v. 37, no. 162, p. 225 (Mid. Dev., Logansport ls., Indiana).

Exterior.—Coenosteum nodular, about 80 mm. in longer diameter; surface undulating, without regular mamelons; astrorhizae imperfect. Latilaminae 5 to 10 mm. thick.

Vertical section.—The laminae, 6 to 7 in 2 mm., are thick, 0.2 to 0.3 mm., tripartite, with thin, clear median line and much thicker lower and upper, maculate layers; laminate cut obliquely do not show the median layer well. Pillars thinner than the laminae, spool-shaped, rarely superposed, and continuous with the lower and upper layers of the laminae, 6 to 8 in 2 mm. Galleries round to elongate horizontally, not as thick as the laminae. Dissepiments scarce;

astrorhizal tubes larger than the galleries but inconspicuous, with tabulae. Maculae large and flocculent. Dissepiments scarce.

Tangential section.—The laminae and pillars are mostly fused; pillars between laminae are round. The tissue is gray and maculate, neither homogeneous nor fibrous. The maculae are mostly small and flocculent but some have a round, central clear spot. Galleries occupy much less space than the laminae, and are irregular in shape and development. Astrorhizal canals are narrow, 0.2 to 0.3 mm., with numerous curved tabulae, and do not form typical astrorhizae.

Comparisons.—This species seems to be perfectly typical of the type from the Logansport limestone of Indiana. It has thicker laminae and narrower galleries than *C. abeona.*

Occurrence.—One good specimen from the Middle Devonian, Ramparts formation, 85 to 130 feet above base, *Radiastrea arachne* Zone, Schooner Creek, near Norman Wells, Northwest Territories. Collected by A. C. Lenz, 1958, locality L30. Princeton University, no. 82705, slide MV2-7. Indiana University, slide 307-94.

Genus HERMATOSTROMA Nicholson, 1886
Type: *H. schluteri* Nicholson, 1886; Lecompte, 1952; Galloway, 1957.

Coenosteum massive; laminae regular; pillars strong, superposed, with light borders; tissue maculate.

HERMATOSTROMA EPISCOPALE Nicholson
Pl. 77, figs. 4a,b

Hermatostroma episcopale NICHOLSON, 1892, Palaeontological Soc. London, v. 46, p. 219, pl. 28, figs. 4–11 (Mid. Dev., England); LECOMPTE, 1952, Inst. Roy. Sci. Nat. Belgique, Mém. 117, p. 260, pl. 48, fig. 4; pl. 49, figs. 1,2 (Up. Dev., Frasnian, Belgium).

Exterior.—Coenosteum nodular; surface with irregular mamelons and large astrorhizae.

Vertical section.—Laminae strong in places, with thin light, median line, or missing and indicated by upwardly curved tabulae. Galleries superposed, appearing as vertical tubes crossed by curved diaphragms. Tissue clearly or obscurely maculate, depending on the preservation. Pillars strong 0.13 to 0.17 in diameter, continous or regularly superposed, about as wide as the galleries, about 7 in 2 mm. Astrorhizal canals large, crossed by tabulae. Dissepiments abundant, much like the tabulae in the tiers of galleries. Light borders of pillars occur but are rarely seen.

Tangential section.—In the laminae the galleries are mostly round, 0.15 mm. in diameter, or vermicular, each enclosed by a clear line inside of a dark line. The pillars join around and between the galleries. Our section does not show round pillars surrounded by a light zone, as does *Hermatostroma schlüteri.* Astrorhizal canals are large, up to 0.55 mm. across, dividing into smaller branches, mostly crossed by curved tabulae. Maculae are obvious in places, in other places obscure.

Comparison.—The Fort Good Hope specimen agrees well with the descriptions and figures of *Hermatostroma episcopale* Nicholson, and of Lecompte.

Occurrence.—Post-*Stringocephalus* Beds, possibly Upper Devonian, Ramparts formation, 240 to 345 feet above the base, Ramparts, near Fort Good Hope, Northwest Territories. Collected by A. C. Lenz, locality L14, Princeton University, no. 83017, slide MV2-8. Indiana University, slide 307-95.

STRATIGRAPHIC REFERENCES

COOPER, G. A., *et al.*, 1942, Correlation of the Devonian sedimentary formations of America: Geol. Soc. America, Bull., v. 53, p. 1729–1794, 1 pl.

HUME, G. S., 1921, North Nahanni and Root Rivers area, and Caribou Island, Mackenzie River district; Geol. Surv. Canada, Sum. Rept., 1922, pt. B, p. 76–78.

——. 1922, Geology of the Norman oil fields and a reconnaissance of a part of the Liard river: Geol. Surv. Canada, Sum. Rept., 1922, pt. B, p. 47–63.

KINDLE, E. M., 1919, The discovery of a Portage fauna in the Mackenzie River valley: Geol. Surv. Canada, Mus. Bull. 29.

MEEK, F. B., 1868, Remarks on the geology of the valley of Mackenzie River, with figures and descriptions of fossils from that region, in the Museum of the Smithsonian Institution, chiefly collected by the late Robert Kennicott, Esq.: Chicago Acad. Sci., v. 1, art. 3.

SMITH, S., 1945, Upper Devonian corals of the Mackenzie River region, Canada: Geol. Soc. America, Special Paper 59.

WARREN, P. S. 1944a, Index brachiopods of the Mackenzie River Devonian: Royal Soc.

Canada, Trans., 3rd ser., v. 38, sec. 4, p. 105–135.

——, 1944b, The role of *Sphaerospongia tessellata* in the Mackenzie River Devonian: Canada Field Nat., v. 58 p. 28–29.

—— & STELCK, C. R., 1950, Succession of Devonian faunas in western Canada: Royal Soc. Canada, Trans., v. 44, ser. 3, sec. 4, p. 61–78.

—— & ——, 1956, Devonian faunas of western Canada: Geol. Assoc. Canada, Special Paper 1, pt. 1, p. 1–15, 29 pls.

WHITEAVES, J. F., 1891, The fossils of the Devonian rocks of the Mackenzie River basin: Geol. Surv. Canada, Contrib. to Canadian Paleontology, v. 1, pt. 3.

WHITTAKER, E. J., 1921, Mackenzie River district between Great Slave Lake and Simpson: Geol. Surv. Canada, Sum. Rept., 1921, pt. B, p. 45–55.

——, 1922, Mackenzie River district between Providence and Simpson, N.W.T.: Geol. Surv. Canada, Sum. Rept., 1922, pt. B, p. 88–100.

PALEONTOLOGIC REFERENCES

BARGATZKY, A., 1881, Die Stromatoporen des rheinisches Devons: Verhandl. naturhist. Vereins Preuss. Rheinlande Westfalens, v. 38, pp. 233–304; separate p. 1–79.

FLÜGEL, E. N. 1956, Zurbibliographie der Stromatoporen, Mitteil: Naturwiss. Vereins Steinmark. bd. 86, p. 28–31. Graz.

——, 1958, Artenrevision von *Actinostroma* Nicholson: Anzeiger math.-naturw. Osterreichen Akad. Wissenschaften, Jahrgang 1958, no. 4, p. 25–29.

FRITZ, M. A. & WAINES, R. H., 1956, Stromatoporoids from the Upper Abitibi River Limestone: Geol. Assoc. Canada, Proc., v. 8, pt. 1, p. 87–126, pls. 1–3.

GALLOWAY, J. J., 1957, Structure and classification of the Stromatoporoidea: Am. Paleontology, Bull., v. 37, no. 164, p. 341–480, 7 pls.

GALLOWAY, J. J. & ST. JEAN, J., 1956, A bibliography of the Order Stromatoporoidea: Jour. Paleontology, v. 30, p. 170–185.

—— & —— 1957, Middle Devonian Stromatoporoidea of Indiana, Kentucky, and Ohio: Am. Paleontology, Bull., v. 37, no. 162, p. 24–308, 23 pls.

GOLDFUSS, A., 1826, Petrefacta Germaniae: List and Francke, Leipzig, 1st ed., p. 21, pl. 8, 2nd ed., 1862.

HALL, J. & WHITFIELD, R. P., 1873, 23rd. Ann. Rept. Reg. Univ. State of New York, p. 233–243, pls. 9,10.

KÜHN, O., 1928, Fossilium Catalogus, 1, Animalia, Pars 36, Hydrozoa: W. Junk, Berlin, p. 1–114.

LECOMPTE, M., 1951–52, Les Stromatoporoides du Devonian moyen et superieur du Bassin de Dinant: Inst. Roy. Sci. Nat. Belgique, Mém. 116, p. 1–215, pls. 1–35; Mém. 117, p. 216–369, pls. 36–70.

NICHOLSON, H. A., 1875, Descriptions of Amorphozoa from the Silurian and Devonian formations: Geol. Survey Ohio, v. 2, pt. 2, p. 245–255, pl. 24.

——, 1886a, On some new or imperfectly known species of stromatoporoids: Ann. Mag. Nat. Hist., ser. 5, v. 17, p. 225–239, pls. 6–8.

——, 1886b, 1889, 1891, 1892, A monograph of the British stromatoporoids: Palaeontological Soc. London, v. 39,42,44,46, pts. 1–5, p. 1–234, pls. 1–29.

——, 1891b, On some new or imperfectly known species of stromatoporoids: Ann. Mag. Nat. Hist., ser. 6, v. 7, pp. 309–328, pls. 8–10.

PARKS, W. A., 1904, Devonian fauna of Kwataboahegan River: Ontario Bur. Mines, 13th Rept., pt. 1, p. 180–191, pls. 1–4.

——, 1936, Devonian Stromatoporoids of North America: Univ. Toronto Studies, geol. ser., no. 39, p. 1–125, pls. 1–19.

RIPPER, E. A., 1937, On the Stromatoporoids of the Buchan District, Victoria: Royal Soc. Victoria, Proc., v. 50, pt. 1, n.s., p. 13–38, pls. 2–5.

YAVORSKY, V. I., 1931, Some Devonian stromatoporoids from the outskirts of the Kuznetsk Basin, the Ural and other localities: Bull., United Geol. and Prosp. Service, U.S.S.R., v. 50, fasc. 94, p. 1387–1415, pls. 1–4.

——, 1955, Stromatoporoidea Sovetskogo Soyuza: Trudy Vsesoyuznogo Nauchno-issledovatelskogo Geol. Inst., Minister. Geol. i Ochrany Nedr., new ser, v. 8, p. 1–173, pls. 1–89.

——, 1957, ibid., v. 18, p. 1–168, 48 pls.

EXPLANATION OF PLATE 77

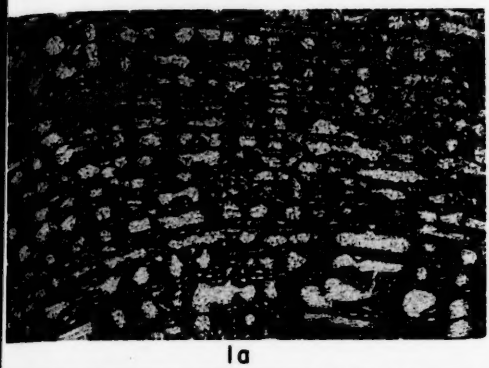
All figures ×10

FIGS. *1—Parallelopora pellucida* (Yavorsky). *a*, Vertical section; and *b*, tangential section. *Rensselandia* Beds. P. U., 83005, slide MV1-22.

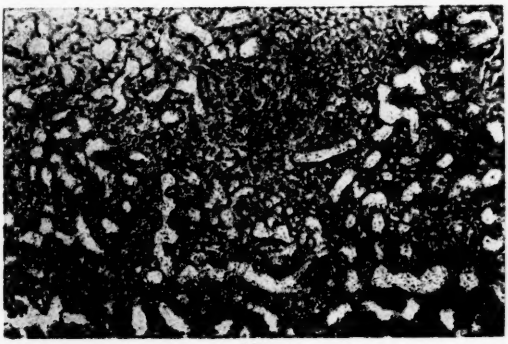
2—Clathrocoilona abeona Yavorsky. *a*, Vertical section; and *b*, tangential section. Kee Scarp Reef. P. U., 83015, slides MV2-5,6.

3—Clathrocoilona restricta Galloway & St. Jean. *a*, Vertical section; a foreign object is near the left center; and *b*, tangential section. *Radiastrea* Zone. P. U., 82705, slide MV2-7.

4—Hermatostroma episcopale Nicholson. *a*, Vertical section; and *b*, tangential section. Post-*Stringocephalus* Beds. P. U., 83017, slide MV2-8.



1a

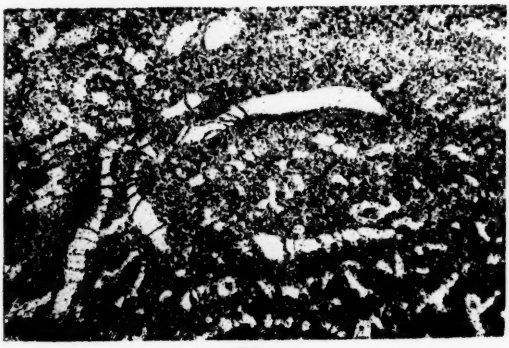


1b

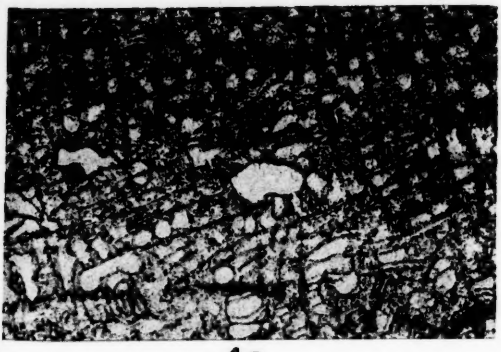
2a

2b

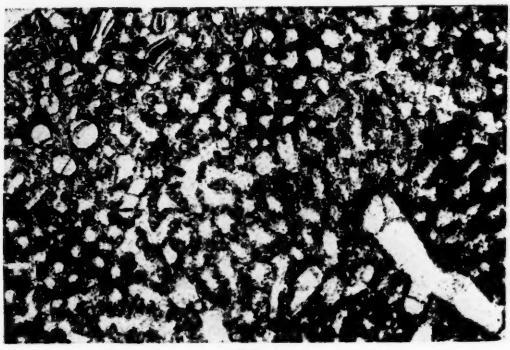
3a



3b

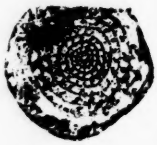


4a



4b

1



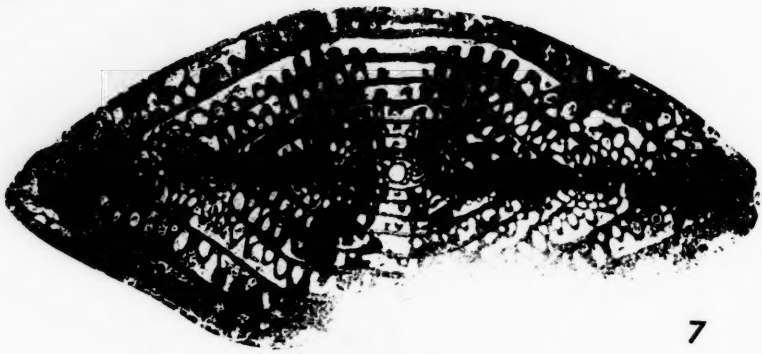
2

3

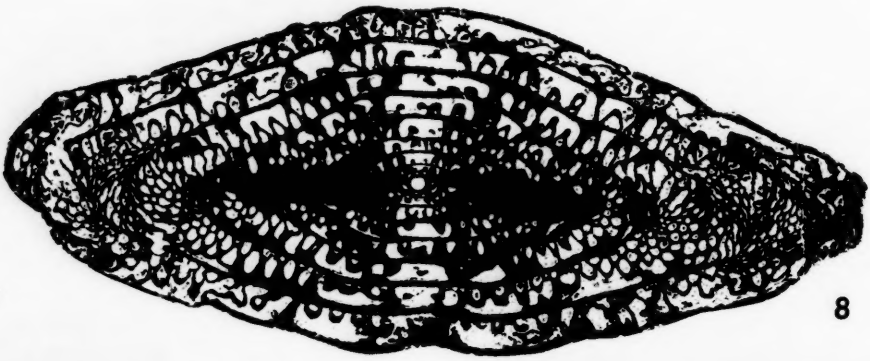
4

5

6

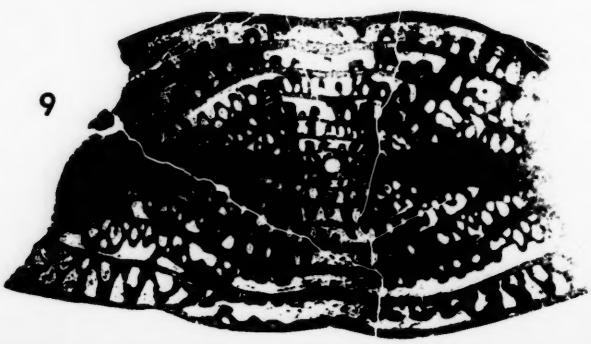


7



8

10



9

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 637–655, PLS. 78–82, 7 TEXT-FIGS., JULY, 1960

PERMIAN FUSULINIDS FROM GUATEMALA

STANLEY A. KLING
Columbia University, New York

ABSTRACT—Upper Paleozoic marine rocks were recognized in Central America late in the nineteenth century, and their character and distribution were made known in a reconnaissance study by Karl Sapper (1896–1937). They occur in a narrow folded and faulted belt, 20 to 25 miles wide, extending eastward from Chiapas, Mexico, through Guatemala to British Honduras. In most places, the sequence can be divided into a lower shale division, several thousands of feet thick, called the Santa Rosa formation by most investigators, and an upper division of one to two thousand feet of limestone and dolomite to which various names have been applied: Grupera, La Vainilla, and Paseo Hondo in Mexico, and Karbonkalk and Chochal in Guatemala. The Upper Paleozoic rocks are thought to overlie, unconformably, older metamorphic rocks, and are overlain, unconformably, by red beds of the Mesozoic Todos Santos formation.

Fossil collections obtained from these rocks by various investigators indicate ages ranging from Carboniferous to Permian. The lower part of the Santa Rosa formation usually has been assigned to the upper Pennsylvanian throughout the outcrop belt. Lower and middle Permian fusulinids have been reported from the limestone sequence in Chiapas and Guatemala. In British Hondura, Pennsylvanian brachiopods have been reported from the lower part of the sequence and a middle Permian ammonoid from near the top.

The present investigation of the upper Paleozoic sequence in Guatemala has provided new and more comprehensive fusulinid collections. Among them, species of the genera *Eoverbeekina*, *Schubertella*, *Schwagerina*, and *Parafusulina* are recognized. One species of each of the four genera was recognized previously in Chiapas, Mexico, and one species of *Parafusulina* in Guatemala. Three new species of *Parafusulina* are described: *P. erratosoptata*, *P. biturbinata*, and *P. subrectangularis*. One identifiable species from the uppermost part of the Santa Rosa formation in Guatemala indicates a Permian age for a few hundred feet of shale near the top of the formation. Similarity of a number of species to forms from the Permian of Texas strongly indicates ages of Wolfcampian, Leonardian, and early Guadalupian for the massive limestone sequence. The Pennsylvanian-Permian boundary, as yet unidentified, evidently lies within the shale section.

The upper Paleozoic sequence appears to change facies from west to east. In Mexico and Guatemala, it consists mainly of shale and limestone with sandstone conspicuously absent, while in British Honduras, sandstones and shales are dominant with only a few thin beds of limestone. A terrigenous source to the east is suggested.

INTRODUCTION

UPPER Paleozoic marine rocks occupy a belt about 20 miles wide in Central America trending east-west from Chiapas, Mexico, through Guatemala to Honduras. These rocks are bordered on the south by younger andesitic eruptives with isolated volcanic cones, and on the north by a concordant series of Mesozoic and younger sedimentary rocks. The Paleozoic rocks are strongly folded and faulted and characterized by rugged mountain topography with peaks reaching 13,000 feet. An index map (Text-fig. 1) shows the general distribution of outcrops of these rocks.

The geology of Central America was first studied by Dollfus & de Mont-Serrat, and their report including a generalized map and

EXPLANATION OF PLATE 78

All figures are ×10

FIGS. *1–6—Eoverbeekina americana* Thompson & Miller. *1,3,6*, Axial sections; *2,4*, sagittal sections; and *5*, oblique section: AMNH 28243, 28244, 28245, 28246, 28247, 28248.

7–10—Schwagerina gruperaensis Thompson & Miller. *7,8,9*, Axial sections; *10*, sagittal section; AMNH 28249, 28250, 28251, 28252.

TEXT-FIG. *1*—Index map of Central America.

description of the upper Paleozoic rocks was published in 1868. During the late nineteenth century, Karl Sapper made several expeditions through Central America gathering geological data and mapping the areas visited. Summaries of his work were subsequently published (1896, 1899, 1906, 1927). In 1937, Sapper published a revised account of Central American geology with minor modifications of previous reports, and most of what is known today of the geology of Central America is largely based on Sapper's excellent reconnaissance work. Among his fossil collections were fusulinids from Guatemala considered to be Carboniferous in age. These were studied by von Staff (1912), who described a new form, *Fusulina verneuili* var. *sapperi*.

Several years later, Dunbar (1939) reinterpreted Sapper's collections augmenting von Staff's brief description. He recognized two species which he assigned to the middle Permian. *Fusulina verneuili* var. *sapperi* was redescribed as *Parafusulina sapperi* Staff, and *Parafusulina guatemalaensis* was introduced as a new species.

Thompson & Miller collected fusulinids from equivalent upper Paleozoic limestones and shales in Chiapas, Mexico, and published the results of their studies in 1944. They described several new species and established correlations with the Hueco (Wolfcampian) limestone and the Leonard formation of Texas.

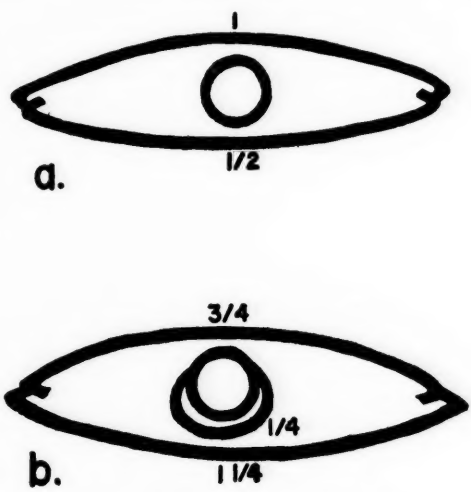
During his surveys, Sapper collected fossils from limestones of British Honduras which he regarded as upper Carboniferous, but Schuchert (1935) assigned these beds to the Permian on the basis of Dunbar's identification of fusulinids from Guatemala.

Dixon (1956) has summarized the geology of Southern British Honduras and assigned a series of sandstones and shales to "Upper Pennsylvanian to Middle Permian" on the basis of Schuchert's classification and his own fossil collections. Pennsylvanian brachiopods, identified by Muir-Wood, were collected from the lower part of the sequence, and the ammonoid, *Perrinites hilli*, from near the top. Apparently no fusulinids have been found in British Honduras.

Roberts & Irving (1957) in a report on the mineral deposits of Central America list identifications by L. G. Henbest of fusulinids from Guatemala. These are recognized mainly to the generic level and are regarded as similar to forms from Chiapas and Guatemala described by Thompson & Miller (1944) and Dunbar (1939), respectively.

During the summer of 1956, the present author was a member of a field party headed by Norman D. Newell and sponsored by the American Museum of Natural History, New York City. Several Permian localities in Mexico and Central America were visited, and two stratigraphic sections in Guatemala were measured, studied, and sampled for fossils, with special attention to fusulinids. The purpose of this project was to obtain detailed information on the Permian rocks of Guatemala and to document more thoroughly their fusulinid faunas. It was further hoped that study of these collections would permit better correlation of the Guatemala rocks with the Permian of Texas. Ultimately the relationships between the Guatemala sections and neighboring sections in Chiapas and British Honduras were to be considered and an attempt made to establish a more definite geologic age for the belt of upper Paleozoic strata in Central America.

The writer is especially indebted to Norman D. Newell of Columbia University and the American Museum of Natural History. John Imbrie of Columbia University also offered valuable suggestions especially concerning the treatment of quantitative data. Jack L. Walper of the University of Texas aided in the location of an important section near Purulhá, Guatemala. Many courtesies were extended by Dr. Jorge A. Ibarra of the Museo National de História Natural, Guatemala City, during the work in Guatemala. G. Robert Adlington of the American Museum of Natural History made the photographs of the fusulinids. The field work in Guatemala was financed by the American Museum of Natural History, and laboratory studies and subsistence at Columbia University were supported, in part, by a grant from the Guatemalan Atlantic Corporation, Sohio Caribbean Company, and Tidewater Guatemala, Ltd.



TEXT-FIG. 2—Orientation of axial sections of fusulinids.

SUMMARY OF STRATIGRAPHY

The narrow belt of upper Paleozoic rocks extending across Central America consists of several thousands of feet of marine rocks, dominantly unfossiliferous dark colored siltstone and sandy shale below, and massive, fine-grained limestone above. These rocks overlie, probably unconformably, poorly exposed serpentine and other metamorphic rocks, but at most places the contact relationships are obscure and are involved in low angle faults. The highest limestones of the Paleozoic are overlain, unconformably but concordantly, by red beds of the early Mesozoic Todos Santos formation.

The lower shales of the Paleozoic have long been called the Santa Rosa formation, following Dollfus & de Mont-Serrat (1868), who took the name from a hacienda about

20 miles south of Cobán in North Central Guatemala. Unfortunately, the rocks at this locality are quite unrepresentative of the lower shale sequence. At Santa Rosa, the exposed sequence consists of many hundreds of feet of unfossiliferous arkosic red sandstone, conglomerate, and red shale. Lithologically it closely resembles the Todos Santos formation and is quite unlike any part of the lower shale sequence elsewhere. Probably the rocks at Santa Rosa Hacienda are a downfaulted block of the Todos Santos formation surrounded by very dissimilar Paleozoic rocks, also termed Santa Rosa by Dollfus & de Mont-Serrat, and by Sapper.

Sapper (1899) used the Santa Rosa formation for dominantly dark shale that crops out in a narrow belt completely across Guatemala. The overlying limestone he termed the "Carbonkalk." On the basis of inadequate fossil evidence, he assigned both the Santa Rosa formation and the Carbonkalk to the Carboniferous.

Although the lower and upper boundaries of the Santa Rosa formation, as used by Sapper, are poorly defined and poorly exposed, the formation is nevertheless a useful stratigraphic unit in the present state of knowledge. It is proposed here to follow the prevalent usage, but excluding the isolated outcrops of red beds at Hacienda Santa Rosa.

Thompson & Miller (1944), in describing the upper Paleozoic rocks of Chiapas, Mexico, tentatively correlated a lower sandstone and dark-colored shale sequence with thin limestones with the Santa Rosa formation of Guatemala (Text-fig. 3). Overlying the clastic beds, three limestone formations were recognized: (1) the Grupera formation with fusulinids indicating equivalency with the Hueco formation (Wolfcampian) of Texas, (2) the La Vainilla limestone with fusulinids younger than Wolfcampian, but possibly older than Leonardian, and (3) the Paseo Hondo formation with both fusulinids and ammonoids clearly indicating correlation with the Leonard formation of Texas.

In British Honduras, the upper Paleozoic rocks consist of several thousands of feet (in excess of 9,000 feet in places) of sandstones grading upwards into shales with a few thin beds of limestone. These are termed the Macal series by Dixon (1956). The sequence is divisible, on the basis of lithological characteristics, into a lower sandstone group and an upper shale group, but the sandstones thicken toward the northeast at the expense of the shales. Fossils collected by Dixon include brachiopods from the lower part of the sequence identified as upper Pennsylvanian by Muir-Wood, and the ammonoid *Perrinites hilli* (Smith) from near the top of the sequence, suggesting a Leonardian age. Limestones similar to those of Guatemala and Chiapas, Mexico, are lacking in British Honduras, where the upper Paleozoic sequence consists of dark-colored terriginous rocks. The lower part of the Macal series must be equivalent to the Santa Rosa formation of Guatemala and, on the basis of classification of some of its beds as middle Permian, part of the Macal series must be equivalent to at least part of the limestone sequence of Guatemala (Text-fig. 3).

Roberts & Irving (1957) revisited the Santa Rosa type locality in Guatemala and included in this formation a section in the Chiantla-San Sebastián area, Department of Huehuetenango, consisting of a lower unit of interbedded sandstone, shale, and conglomerate, and an upper unit with interbedded limestone, sandstone, and dolomite. It was their opinion that beds equiva-

---

EXPLANATION OF PLATE 79

FIGS. *1–6—Schubertella muellerriedi* Thompson & Miller. *1,4,5*, Axial sections, ×20; *6*, tangential section, ×20; *3*, sagittal section, ×20; and *2*, matrix with several specimens, ×10; AMNH 28253, 28254, 28255, 28256, 28257, 28258.

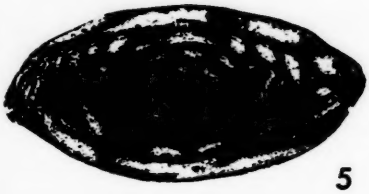
7–10—Parafusulina species. *7,9,10*, Axial sections, ×10; and *8*, tangential section ×10; AMNH 28259, 28260, 28261, 28262.

2

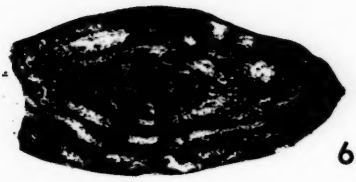
3

1

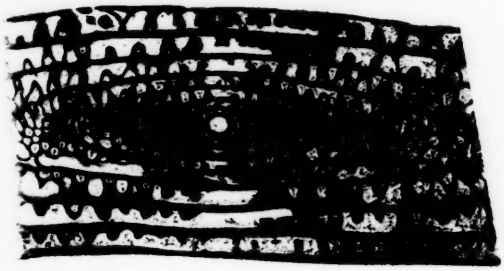
4



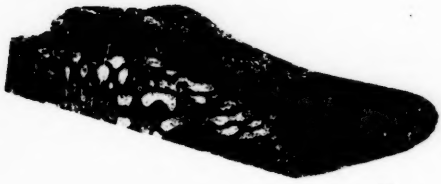
5



6

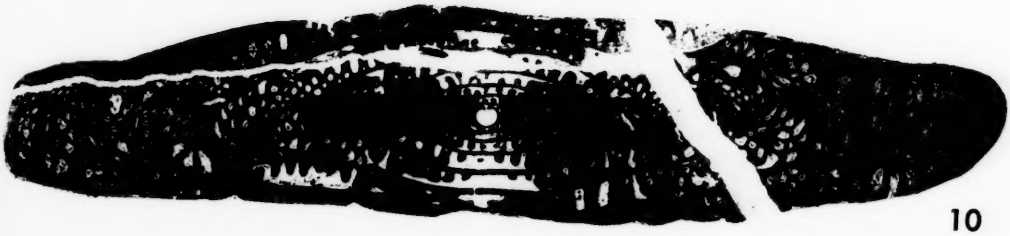


7

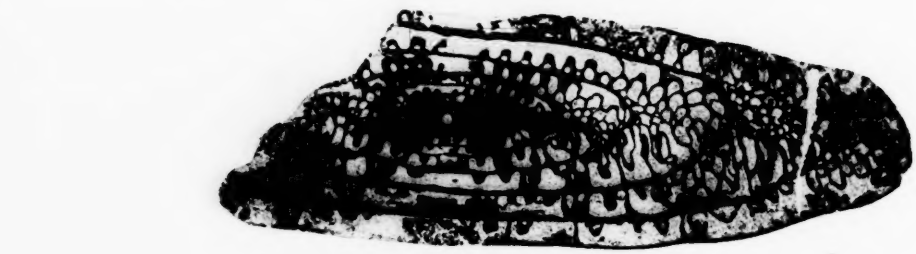


8

9



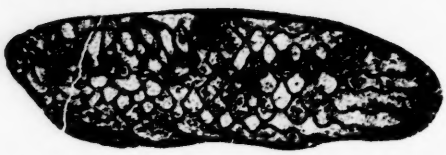
10



1

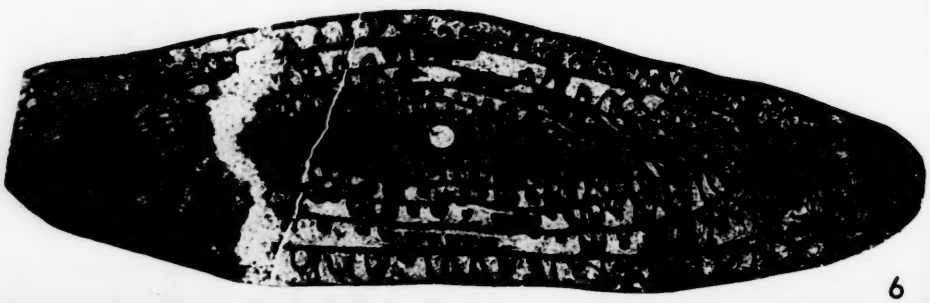
2

3

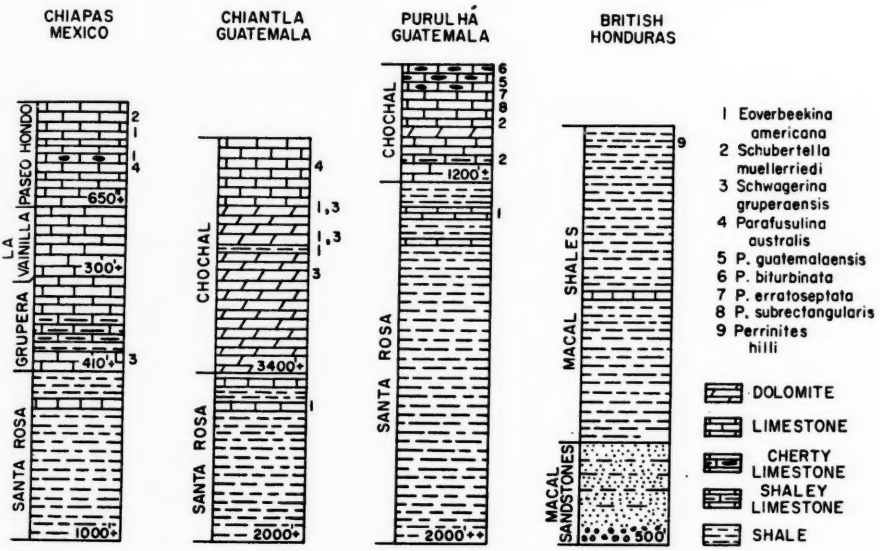


4

5



6



TEXT-FIG. 3—Stratigraphic sections in Central America.

lent to the Grupera and La Vainilla formations of Mexico could be recognized within the Santa Rosa formation. Above the Santa Rosa formation of the Chiantla area lie limestones named the Chochal limestone by Roberts & Irving (Text-fig. 3). According to Henbest, fossils (mainly fusulinids) from the limestones indicated equivalency with the upper part of the La Vainilla limestone and the Paseo Hondo formation of Chiapas.

Two detailed sections in Guatemala were measured by the field party under Dr. Newell. One of these was located near Chiantla, and the other 85 miles to the east at a mine prospect (Suquinay) near Purulhá, Department of Baja Verapaz. The locations of these places are shown on the index map (Text-fig. 1). Both sections consist of a thick (in excess of 2,000 feet) lower shale sequence with a few thin beds of limestone, overlain by a continuous limestone sequence of 1,000 to 2,000 feet thickness. The basal contact of the shale sequence was not exposed at either locality.

The limestones are mainly pure even beds of calcarenite in which fusulinids and codiacean algae are generally the only recognizable fossils. The thin and infrequent terriginous beds within the limestone sequence are similar to the dark gray argillaceous shales of the Santa Rosa formation. Quartz siltstones, sandstones, red beds, and evaporites are conspicuously absent. Otherwise, the prevailing facies is remindful of the marginal backreef limestones around the Delaware Basin of Texas.

The massive limestones of the Chiantla section contain several dolomitic beds. Fusulinids of the upper beds are also found in the La Vainilla limestone and Paseo Hondo formation of Chiapas. The limestones of the Purulhá section contain fewer dolo-

EXPLANATION OF PLATE 80

All figures are ×10

FIGS. *1–3*—*Parafusulina australis* Thompson & Miller. *1,2*, Axial sections; and *3*, tangential section; AMNH 28263, 28264.

4–6—*Parafusulina erratoseptata* Kling, n. sp. *4*, Tangential section; and *5,6*, Axial sections; AMNH 28266, 28267, 28268.

DESCRIPTION OF STRATIGRAPHIC SECTIONS

Stratigraphic Section near Chiantla Huehuetenango, Guatemala

Starting south-southwest of the Santo Domingo mine.

Bed Number	*Mesozoic Sequence*	*Thickness*
14	Gray dolomite, thick-bedded. Fault contact.	several hundred feet
	Todos Santos Formation	
13	Red shale with a few thin beds of hard sandstone. At base, 50 feet of conglomerate with limestone pebbles in red sandstone matrix. Ridge forming sandstone at top. Fault contact.	estimated 4,000 feet
	Permian Sequence	
	Chochal limestone	
12	Limestone, dark gray, with scattered silicified brachiopods.	600 feet
11	Dark gray limestone with a few silicified brachiopods. *Parafusulina australis* common.	75 feet
10	Bedded black to dark gray limestone with scattered silicified brachiopods: *Composita*, rhynchonellids, and *Dictyoclostus*.	320 feet
9	Cliff-forming, bedded limestone. *Schwagerina gruperaensis* common at base. *Eoverbeekina americana* scattered throughout. A few productid brachiopods.	50 feet
8	Dark gray, dolomitic limestone. *Eoverbeekina americana* collected at 90, 215, and 300 feet above the base, associated with *Bellerophon*. *Schwagerina gruperaensis* rare.	560 feet
7	Shale, gray brown.	15 feet
6	Massive, dolomitic, dark gray limestone. *Eoverbeekina americana* and *Schwagerina gruperaensis* rare near top associated with *Bellerophon*.	585 feet
5	Limestone, dark gray, recrystallized, with thin gray shale.	30 feet
4	Cliff-forming, massive dolomitic limestone. Dark gray, recrystallized.	estimated 1,000 feet
3	Shale and limestone, covered.	100 feet
2	Limestone, poorly exposed.	100 feet
1	Dark shale, several thousand feet thick. One or more thin limestone beds near top. *Eoverbeekina americana* and *?Parafusulina* collected from a road cut on the Pan American Highway, 6.6 miles west of San Rafael and 30 miles west of Huehuetenango, come from a dark gray limestone member, 15 feet thick, lying approximately 300 feet below the top of the unit.	
Minimum thickness of known exposed Permian.		5,435 feet

Stratigraphic Section near Purulhá Baja Verapaz, Guatemala

Base of section begins at, and proceeds upwards from, the entrance to the Suquinay mine. Sequence entirely Permian.

Bed Number		*Thickness*
	Chochal limestone	
21	Cherty, blue gray limestone with abundant "cornflakes" algae. *Parafusulina guatemalaensis* common near the bottom and *P. biturbinata* common near the top.	180 feet to limit of exposure
20	Well-bedded, blue gray cherty limestone. "Cornflakes" algae very abundant. *Parafusulina erratoseptata* common at top.	120 feet
19	Limestone, well bedded, blue gray. *Parafusulina erratoseptata* common.	32 feet
18	Cherty, blue gray limestone with "cornflakes" algae and rare, crushed fusulinids (*Parafusulina*).	30 feet
17	Fine-grained, blue gray limestone with abraded fusulinids (*Parafusulina sp.*).	25 feet

Bed Number	Permian Sequence	Thickness
16	Limestone, blue gray, fine-grained. *Schubertella muellerriedi* abundant, *Parafusulina subrectangularis* common.	60 feet
15	Limestone, covered.	130 feet
14	Fine-grained, bluish gray limestone with brachiopods and large *Bellerophon*. *Schubertella muellerriedi* and *Parafusulina subrectangularis* common at top.	50 feet
13	Dolomitic, bluish gray limestone containing large *Bellerophon*. *Parafusulina subrectangularis* rare.	105 feet
12	Limestone, covered.	55 feet
11	Limestone.	15 feet
10	Covered.	12 feet
9	Limestone, blue gray, with dasycladacian algae and numerous large *Bellerophon*.	40 feet
8	Limestone with minor amounts of shale. *Schubertella muellerriedi* abundant.	135 feet
7	Limestone, blue gray, containing dasycladacian algae.	45 feet
6	Limestone, blue gray, with *Schubertella muellerriedi* at top.	25 feet
5	Limestone, covered.	45 feet
4	Limestone, blue gray, shattered, containing shell fragments.	12 feet
3	Shaly limestone, reddish at bottom and top.	13 feet
2	Gray limestone, badly shattered.	7 feet
	Santa Rosa Formation	
1	Shale and limestone, mainly covered or not in place. Bed A: limestone containing *Eoverbeekina americana*, estimated at 300 feet below the top of bed 1. Bed B: limestone containing *?Parafusulina*, estimated at 500 feet below the top of bed 1.	several thousand feet
Minimum thickness of Permian section.		3,176 feet

mitic beds with some cherty beds near the top. One fusulinid species in the lower part of this limestone is also found in the upper part of the Paseo Hondo formation, and above it there are several more advanced species. Thus it appears that the limestones of the Purulhá section may be mainly younger than those of the Chiantla section. The regional stratigraphic relationships in Guatemala are not yet well known, however, and the massive limestones of both areas may roughly correspond to the Chochal limestone of Roberts & Irving. Likewise, the dominantly shaly units will be classed here as Santa Rosa in conformance to the work of many earlier investigators.

Only one fusulinid species (*Eoverbeekina americana*) could be confidently identified from the Santa Rosa formation. It occurs in thin limestones of the upper few hundred feet of the Santa Rosa formation of both sections, and also in the Chochal limestone of the Chiantla section (Text-fig. 3). There are only a few species of this genus known, and *E. americana* is known from only one other locality in North America, Chiapas, where it is restricted to the Paseo Hondo formation. The genus, so far, ranges from Leonardian to Guadalupian. Therefore, an age assignment based on this single form is unwarranted. It is probable that the Santa Rosa formation contains beds of upper Pennsylvanian to lower Permian age.

The Chochal limestone of the Chiantla area contains fusulinids also found in Chiapas. These are similar to forms of Wolfcampian and Leonardian ages of Texas. The Chochal limestone of the Purulhá section, on the other hand, contains fusulinids similar to forms of Leonardian and early Guadalupian (Word) ages of Texas. One of the lowest of these (*Schubertella muellerriedi*) is found in the upper part of the Paseo Hondo formation of Chiapas, above forms found near the top of the Chiantla section. This suggests the possibility that the limestones of the Purulhá section are younger than those of the Chiapas and Chiantla sections and that these may be represented by shale at Purulhá.

In conclusion, fusulinids strongly indicate a Wolfcampian to Leonardian age for the Chochal limestone at Chiantla, and a Leonardian to early Guadalupian age for the Chochal at Purulhá (Text-fig. 3.)

METHODS OF STUDY AND DESCRIPTION

In general, the methods used here are those commonly employed in the study of fusulinids and described in various works treating this group of fossils (Dunbar & Skinner, 1937; Dunbar & Henbest, 1942; Thompson, 1948). Some modifications of standard procedure, however, were found to be advantageous. It is the minor innovations that will be discussed here.

It was not possible to obtain specimens free from the matrix since, in every case, the fusulinids occurred in a very compact, partially recrystallized limestone. A small dentist's drill equipped with a "separating disc" (a thin disc of carborundum bonded with hard rubber) was used to cut small rectangular wedges of rock containing visible individual specimens. This was accomplished by making four incisions in the form of a rectangle around the desired fusulinid. The grooves converged slightly inward so that a wedge containing the fusulinid could easily be freed by gently forcing a screw driver into one of the grooves. A prying action was avoided to prevent breakage. In this manner many of the fusulinids obtained were already sectioned along one side. With some experience, the writer could choose specimens oriented in desired planes (axial, sagittal, tangential). Then, by polishing the exposed surface of the fusulinid and observing under a microscope the migration of the volution outlines at intervals during grinding, adjustments of orientation were made by applying relatively more pressure on one or another side of the specimen.

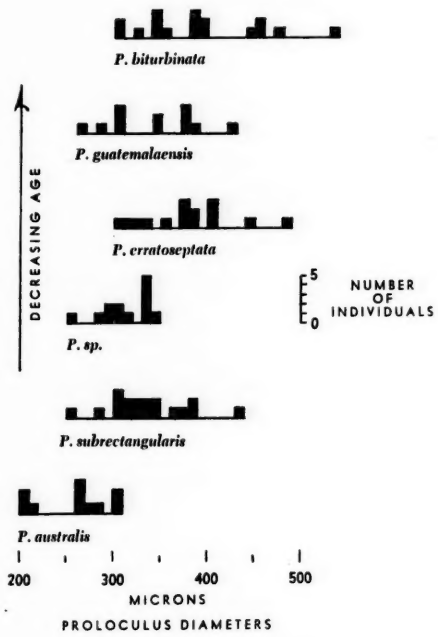
From this stage, thin sections were prepared in a conventional manner. Since optical properties of the sections were not to be studied, it was decided to omit the time-consuming operation of mounting cover glasses on the slides and, instead, to wet each slide with glycerine for study. This was found to give better optical resolution than a dry slide and did not evaporate while the slide was being studied under the microscope.

The possibility of using cellulose peels in the study of fusulinids was investigated. This technique consists essentially of (1) grinding flat and polishing the surface to be studied, (2) etching that surface in weak acid, and (3) pressing the etched surface onto a sheet of cellulose acetate that has been softened by acetone. In this case, it was found more advantageous to dip the specimen into the acetone, but the solvent can be applied directly to the acetate before the impression is made. A 5 percent solution of hydrochloric acid was used, and the etching time varied between five and 15 seconds, depending on the composition of the rock. Five minutes was allowed for drying and the peels removed from the specimens. Peel techniques and their applications and advantages to invertebrate paleontology are discussed in more detail by Sternberg & Belding (1942), Dunbar (1954), and Morikawa (1955). Satisfactory results were obtained for some types of preservation, with features as minute as alveolar wall structure being visible under the microscope. It was not possible, however, to obtain enough etched relief on the limestones from Guatemala to make a satisfactory impression, regardless of the etching time or the strength or composition of the acid. Apparently the rock is of such homogeneous composition that both fossil and matrix dissolve at the same rate. Therefore, cellulose peels were not used for this study. Attempts to stain the specimen before making the impression did not appreciably improve results obtained with unstained specimens.

Measurements were made from axial and sagittal sections according to procedures recommended by Burma (1942). A standard binocular microscope of 75× power was used. Estimates of the number of whorls to the nearest $\frac{1}{4}$ volution in the axial sections were obtained in the following way. Specimens cut along the axis were found to exhibit one of two general patterns in the initial volutions as shown in Text-figure 2. In one case (Text-fig. 2a), the first two half-volutions following the proloculus were of nearly equal length and met at their ends to form an ellipse. Here, the shorter of the first two half-volutions was assumed to lie in the first $\frac{1}{2}$ volution, and its counterpart on the opposite side of the proloculus, to lie in the first even volution. In the second case (Text-fig. 2b), the first half-volution was but slightly wider and longer than the proloculus, with the following two forming

an ellipse similar to that of the first two half-volutions of the previous case. Here, it was assumed that the first half-volution, the one without an opposite counterpart, lay in the first $\frac{1}{4}$ volution; that the shorter of the first "regular" half-volutions lay in the $\frac{3}{4}$ volution; and that its counterpart lay in volution $1\frac{1}{4}$. This method was adapted from one devised by Burma (1942) for *Triticites* and appears to give the best possible accuracy obtainable from axial sections. Measurements made at uneven volutions were corrected to the nearest even volution by (1) plotting the actual measurements on graphs, and (2) interpolating and reading values for even volutions from the graphs.

For presentation of the quantitative data, the usual form has been abandoned in favor of a graphical form similar to one recommended by Burma (1942) and used by several students of fusulinids. Accordingly, measurements are plotted on a logarithmic scale against the corresponding volutions on an arithmetic scale. Lines connect the arithmetic mean values for each volution and the maxima and minima for each volution. It has been pointed out by Burma that this actually results in a double logarithmic plot since the distance around succeeding volutions increases logarithmically. Form ratios have also been shown as arithmetic plots of half length against radius vector. This was done in order to eliminate, at least for this character, the problem of exact angular orientation for each measurement. The reduced major axis which does not assume independence of either of the variables was chosen as the line to best represent the plotted points. A concise description of this graphical method and its use in the study of fossil populations is given by Imbrie (1956).



TEXT-FIG. 4—*Parafusulina*. Proloculus diameters.

EVOLUTIONARY TRENDS

In attempts to recognize evolutionary trends in the parafusulinids, which were well represented by distinctive forms at each stratigraphic horizon, summary graphs for each character were plotted. These consisted of sigmoidal curves defined by arithmetic mean values of measurements plotted on a logarithmic scale versus corresponding volutions on an arithmetic scale, similar to those used to illustrate the measurements. A separate curve was plotted for each stratigraphic horizon. These graphs, however, failed to show any consistent trends. When plotted on the same coordinate axes, the sequence of curves did not correspond to the stratigraphic sequence and was not the same for different measurements. Nor was the sequence of curves for one character the same throughout ontogeny.

There is a very general tendency for average axial length to increase in younger forms in the Guatemalan sequences. But one of the shortest species occurs at the top of the section at Purulhá.

Though still not perfectly consistent, a trend toward larger proloculus diameters in younger forms is suggested by histograms representing this measurement. These are shown in Text-figure 4, in stratigraphic sequence with the oldest species at the bottom. It is probable that this trend would be better defined if larger sample sizes were available.

It appears, then, that the sequence of parafusulinids does not represent a simple evolutionary series and that lateral migrations are, at least in part, responsible for the

distinctive forms that occur at each fusulinid-bearing horizon.

The possible evolutionary significance of cuniculi in *Parafusulina* is a subject of considerable interest. Though the dimensions of cuniculi are difficult to measure, it has been suggested by Coogan (1958) that the distribution of cuniculi among the volutions is of importance in determining phyletic relationships.

Coogan differentiates four groups of species within the genus *Parafusulina* on the basis of general shape and the presence of cuniculi in inner and/or outer volutions. The first group is similar to *Parafusulina wordensis* Dunbar & Skinner with elongate fusiform to elongate subcylindrical shells and cuniculi in the inner whorls. They are early Guadalupian in age. The second group, represented by *P. schucherti* Dunbar & Skinner, are fusiform to elongate fusiform with cuniculi restricted to the outer few volutions and are Leonardian to early Guadalupian. The third group is represented by the single species *P. gracilis* (Meek). Its members are small and elongate with cuniculi restricted to the outer volutions. They occur in the Wolfcampian McCloud limestone. The fourth group apparently occurs only in Asia and its characteristics are somewhat obscure. It is implied that cuniculi are restricted to the outer volutions of older forms and that, in some younger forms, cuniculi occur in both inner and outer volutions.

Several specimens of each species of *Parafusulina* from Guatemala were examined in polished section at one volution intervals to determine in which volutions cuniculi were present. In specimens of *Parafusulina biturbinata*, which is the youngest species collected at Purulhá and probably the youngest of all the Guatemalan species, cuniculi first appear in the second or third volution and continue throughout all volutions to the last. Though this species is considerably smaller than *P. wordensis* and does not resemble it in shape, presence of cuniculi in early volutions seems to substantiate its similarity to other species from the Word formation of Texas. Other species of *Parafusulina* (*P. australis*, *P. erratoseptata*, *P. subrectangularis*, and *P. guatemalaensis*) have cuniculi restricted to the outer two or three volutions. These are fusiform to elongate fusiform and subcylindrical forms corresponding generally to Coogan's second group of which *P. schucherti* is the representative. Thus, the evidence supports the similarity of these species to Leonardian and early Guadalupian forms.

COMPARABLE CENTRAL AMERICAN AND TEXAS FUSULINES

Guatemala	*Chiapas*	*Texas*
Parafusulina biturbinata (Chochal)		*Parafusulina boesei* (Word)
		P. splendens (Word)
P. guatemalaensis (Chochal)		*P. boesei attenuata* (Word)
		P. splendens (Word)
		P. bakeri (Leonard)
		P. fountaini (Leonard)
P. erratoseptata (Chochal)		*P. fountaini* (Leonard)
P. subrectangularis (Chochal)		*P. sellardsi* (Word)
P. australis (Chochal)	*P. australis* (Paseo Hondo)	
Schubertella muellerriedi (Chochal)	*Schubertella muellerriedi* (Paseo Hondo)	*Schubertella melonica* (Leonard)
Schwagerina gruperaensis (Chochal)	*Schwagerina gruperaensis* (Grupera)	*Schwagerina diversiformis* (Wolfcamp)
Eoverbeekina americana (Santa Rosa, Chochal)	*Eoverbeekina americana* (Paseo Hondo)	

SYSTEMATIC DESCRIPTIONS

Family FUSULINIDAE Moeller
Subfamily SCHUBERTELLINAE Skinner
Genus SCHUBERTELLA Staff & Wedekind
SCHUBERTELLA MUELLERRIEDI Thompson & Miller
Pl. 79, figs. 1–6

Schubertella muellerriedi THOMPSON & MILLER (1944), Jour. Paleontology, v. 18, p. 488, pl. 79, figs. 5–11.

This is a minute species generally ellipsoidal in shape with convex lateral slopes and straight axis of coiling. Mature individuals consist of six or seven volutions, the first one or two of which are coiled in endothyroid fashion with their axis of coiling at some angle, up to 90 degrees, to that of the later fusiform volutions.

The outside diameter of the proloculus ranges from 40 to 81 microns in 20 individuals, averaging 60 microns. It does not appear likely that both micro- and megalospheric tests fall within this range, although such was the case in *Schubertella melonica* Dunbar & Skinner which has a similar range of proloculus diameters (Dunbar & Skinner, 1937). Specimens of *S. muellerriedi* with relatively large proloculus diameters are themselves larger than average.

The septa are essentially straight throughout the length of the test. Average septal counts for three individuals are 10, 12, 14, 17, 18, and 22 for the first through sixth volutions respectively.

The spirotheca consists of a relatively thin tectum and a thicker, translucent diaphanotheca. The latter layer is difficult to observe, but has been detected throughout the length of the shell in at least the fusiform volutions. Thicknesses of the combined layers are shown in Text-figure 5.

Tunnel angles range from 20 degrees in the second volution to 50 degrees in the sixth with a consistent tendency to increase during ontogeny. There are distinct chomata in the fusiform whorls. They are somewhat steeper on the side facing the tunnel and are most conspicuous in the middle volutions.

Measurements of this species are shown in Text-figure 5.

Discussion.—Individuals of *Schubertella muellerriedi* are among the largest known in the genus. Its closest relative is *S. melonica* Dunbar & Skinner of the upper Leonard formation of Texas. The two species are very similar in shape, but the latter is smaller, has a generally larger proloculus in the megalospheric forms, and appears somewhat more globose, generally having a smaller form ratio at maturity and at earlier volutions. There is but slight resemblance to *S. kingi* Dunbar & Skinner of the Texas Wolfcampian. That species is considerably smaller in all dimensions and is more elongate.

Occurrence.—*Schubertella muellerriedi* is abundant in the middle part of the Chochal limestone at Purulhá, Guatemala.

Subfamily VERBEEKININAE Staff & Wedekind
Genus EOVERBEEKINA Lee
EOVERBEEKINA AMERICANA Thompson & Miller
Pl. 78, figs. 1–6

Eoverbeekina americana THOMPSON & MILLER (1944), Jour. Paleontology, v. 18, p. 492, pl. 80. figs. 3–6, pl. 83, figs. 3–7.

This species is subspherical in shape, somewhat wider than long at maturity. The polar regions are generally umbilicate with the polar areas of the outer four or five volutions more depressed than in the proceeding ones. Mature specimens possess approximately 11 volutions, attaining a length of 2.0 mm. However, the state of preservation of these forms is exceedingly poor, and their outer volutions appear in many cases to have been abraded. It is possible that abrasion accounts for the smaller dimensions of individuals compared to those described by Thompson & Miller from Mexico. The form ratio is less than one for most volutions and compares favorably with that of the Chiapas forms at corresponding volutions.

Outside diameters of the proloculi measure between 80 and 100 microns. Again these values are not completely reliable since the centers are least well preserved.

Septal counts for the first nine volutions of a characteristic individual are 10, 13, 14, 17, 19, 22, 24, 25, and 28 respectively. Septa are inclined slightly forward and are unfluted from pole to pole.

The spirotheca consists of a thin dense

tectum, a thicker, less dense layer, and, below that, another thin dense layer. There is a suggestion of alveoli-like structures in the middle layer. Thicknesses of these combined layers are shown in Text-figure 5.

It was not possible to trace the path of the tunnel with certainty, but where visible, it appears to single in the inner volutions, bifurcating at about the fifth volution. Foramina are occasionally visible in beyond the seventh volution. Chomata border the tunnel of the inner volutions, and parachomata are poorly developed between adjacent foramina. It is probable that the latter are restricted to areas very near the septa.

Measurements of this species are shown in Text-figure 5.

Discussion.—Despite a considerable range of dimensions, specimens from this collection are so similar in appearance as to hardly warrant placing some of them in a separate species. It is probable that discrepancies in length, width, and proloculus diameter are attributable to the poor state of preservation of the Guatemalan forms. These are somewhat smaller (shorter and narrower) than the individuals from Chiapas. This is the only known species of the genus *Eoverbeekina* in the Western Hemisphere and is not sufficiently similar to other known species to necessitate specific comparisons.

Occurrence.—*Eoverbeekina americana* is abundant in the middle part of the Chochal limestone at Chiantla, Guatemala, and in the upper part of the Santa Rosa formation at both Chiantla and Purulhá, Guatemala.

Subfamily SCHWAGERININAE
Dunbar & Henbest
Genus SCHWAGERINA Moeller
SCHWAGERINA GRUPERAENSIS
Thompson & Miller
Pl. 78, figs. 7–10

Schwagerina gruperaensis THOMPSON & MILLER (1944), Jour. Paleontology, v. 18, p. 495, pl. 79, figs. 1–4.

Axial sections of this species are roughly hexagonal. The middle third is cylindrical and the ends are conical; the lateral slopes are steep and the poles rather sharply pointed. Mature specimens consist of eight volutions of which the outer six or seven exhibit the same outline. The axis of coiling is straight.

The proloculus is spherical. Outside diameters of 16 specimens ranged from 200 to 380 microns, averaging 290 microns. These are somewhat, but not significantly, smaller than the proloculi of the Mexican specimens studied by Thompson & Miller.

Septal fluting is intense with folds of adjacent septa meeting to form closed chamberlets. No cuniculi were observed.

The spirotheca consists of a thin tectum and a thick, coarsely alveolar keriotheca which becomes markedly thicker toward the center of the test. Thicknesses of the combined layers are shown in Text-figure 5.

Tunnel angles range between 20 and 40 degrees with no apparent tendency to increase during ontogeny.

Septal counts for the first through seventh volutions of a characteristic individual were 8, 21, 23, 24, 25, 31, and 42 respectively.

In typical specimens, a dense secondary deposit fills a narrow polar region, as well as areas adjacent to the tunnel, with intervening lateral regions relatively free of such deposits. These rather distinctive fillings are commonly found in all volutions.

Measurements of this species are shown in Text-figure 5.

Discussion.—This species is similar in shape to *Schwagerina guembeli* Dunbar & Skinner of the Leonard formation of Texas which is considerably shorter, somewhat narrower, and therefore has a larger form ratio. The latter species also has fewer volutions and a different distribution of secondary deposits. *S. gruperaensis* bears

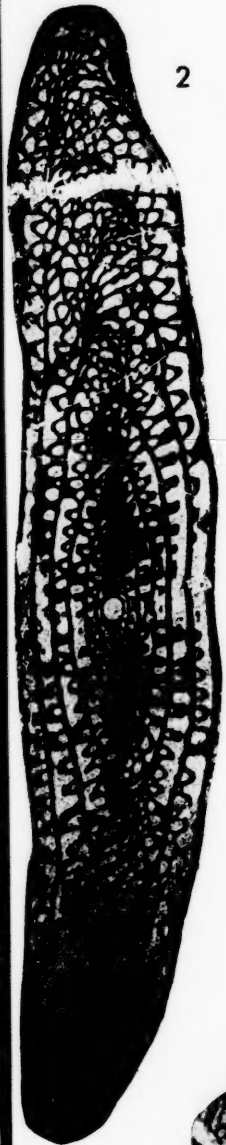
EXPLANATION OF PLATE 81

All figures are ×10

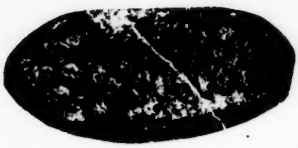
FIGS. *1–3,6*—*Parafusulina guatemalaensis* Dunbar. *1,2*, Axial sections; *3*, tangential section; and *6*, sagittal section; AMNH 28269, 28270, 28271, 28274.

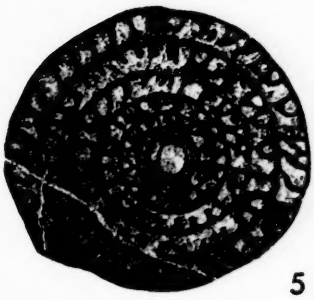
4,5,7–9—*Parafusulina biturbinata* Kling, n. sp. *4*, Tangential section; *5*, sagittal section; and *7,8,9*, axial sections; AMNH 28272, 28273, 28275, 28276, 28277.

1

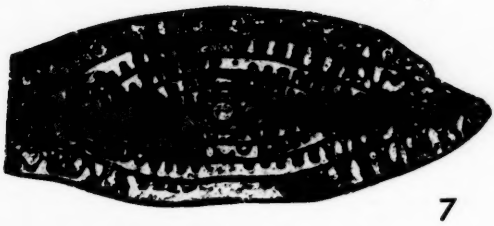

2

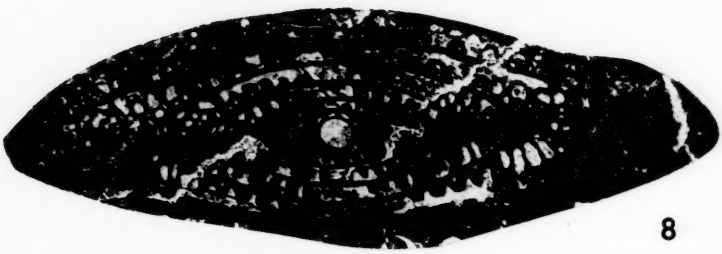
3

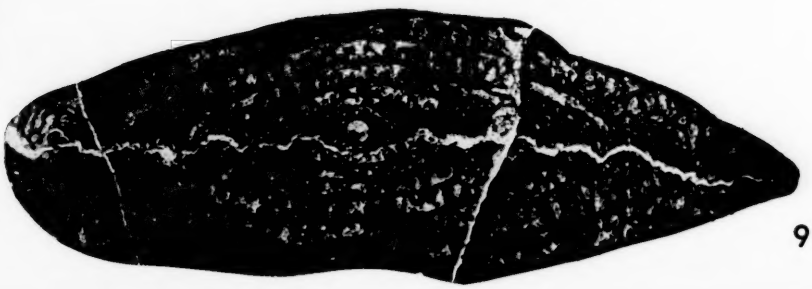

4

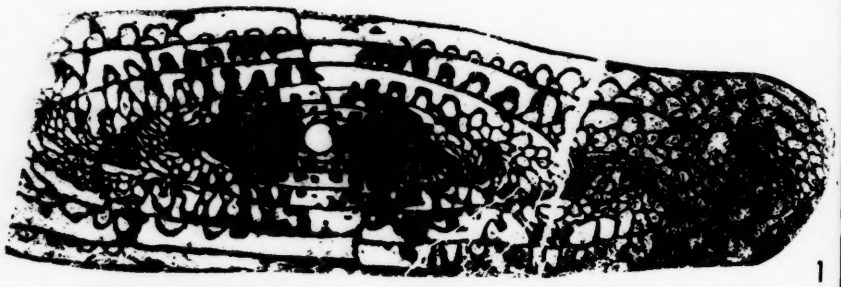

5

6

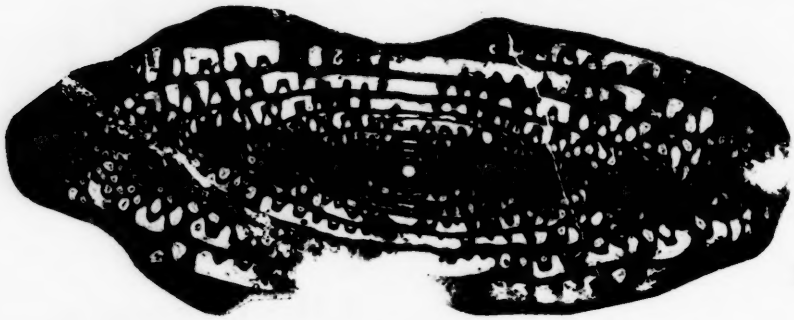

7


8

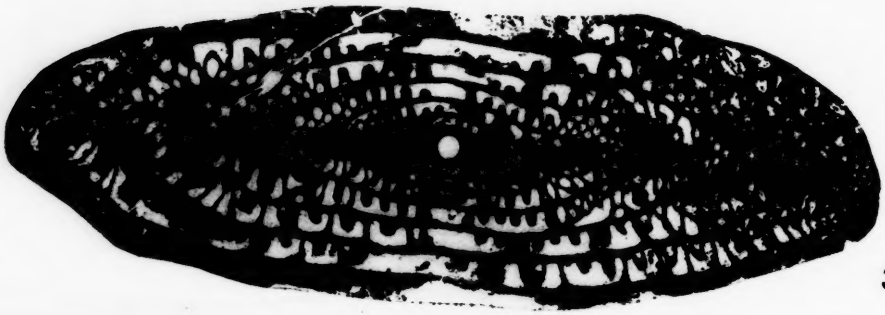

9



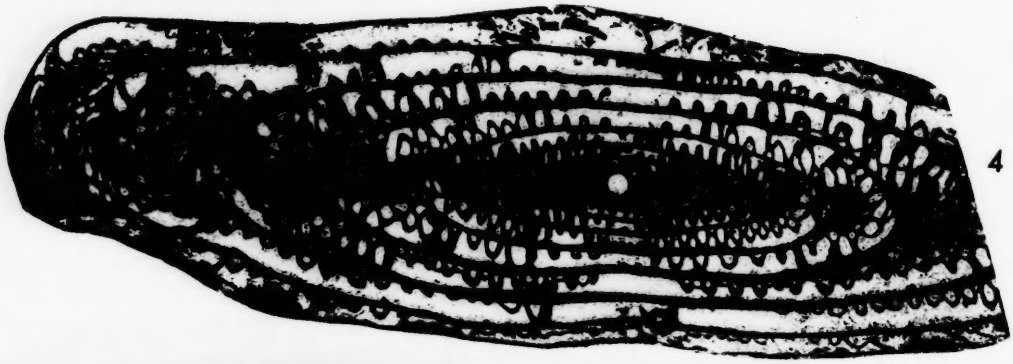
1



2



3



4

5

some resemblance to *S. diversiformis* Dunbar & Skinner of the Texas Wolfcampian as figured by Thompson (1954), but the latter species is generally larger with a larger form ratio and smaller proloculus. The distinctive hexagonal profile, as well as a rather unusual secondary deposit, should serve easily to distinguish *S. gruperaensis* from similar species.

Occurrence.—Schwagerina gruperaensis is common in the middle part of the Chochal limestone at Chiantla, Guatemala.

Genus PARAFUSULINA Dunbar & Skinner
PARAFUSULINA AUSTRALIS
Thompson & Miller
Pl. 80, figs. 1–3

Parafusulina australis THOMPSON & MILLER (1944), Jour. Paleontology, v. 18, p. 503, pl. 81, figs. 2–9.

This is an elongate species, cylindrical at the middle, with conical ends, straight to somewhat convex lateral slopes, and pointed poles. The test has the same general shape throughout ontogeny, and the axis of coiling is straight. Mature specimens have seven to eight volutions.

Outside diameters of the proloculi of ten specimens ranged from 210 to 310 microns, averaging 273 microns.

Septal counts of the first to seventh volutions of a characteristic individual were 10, 18, 20, 26, 29, 29, and 31, respectively. Septal fluting is in the advanced stage characteristic of the genus with cuniculi present, but rather low, narrow, and easily overlooked.

Tunnel angles of a few measurable specimens ranged from the order of 25 degrees in early volutions to the order of 50 degrees in the outer volutions.

The spirotheca consists of a thin tectum and a distinctly alveolar keriotheca. Thicknesses of the combined layers are shown in Text-figure 6.

Low chomata are observable in the first two volutions of most specimens. Heavy secondary deposits fill the regions from the axis to the tunnel of the inner three to four volutions.

Measurements of this species are shown in Text-figures 6 and 7.

Discussion.—A few exceptional specimens of this collection bear a resemblance to *Parafusulina schucherti* of the Bone Spring formation (Leonardian) of Texas. However, *P. australis* is smaller, has a smaller form ratio, and a smaller proloculus. Also, *P. schucherti* is not cylindrical in the equatorial sector as is *P. australis*. Whenever sufficient specimens are available, the two species can plainly be distinguished. The similarity of *P. australis* to *Schwagerina crassitectoria* Dunbar & Skinner and *S. guembeli* Dunbar & Skinner, both of the Texas Leonard, and to *S. franklinensis* Dunbar & Skinner of the Wolfcampian of Texas, was pointed out by Thompson & Miller and is recognized here. In addition to lacking cuniculi, there are differences in general shape, size, and distribution of secondary deposits that serve to distinguish these forms from *P. australis*. *P. australis* is found in the Paseo Hondo formation of Chiapas.

Occurrence.—Parafusulina australis is common in the upper part of the Chochal limestone at Chiantla, Guatemala.

PARAFUSULINA GUATEMALAENSIS Dunbar
Pl. 81, figs. 1–3, 6

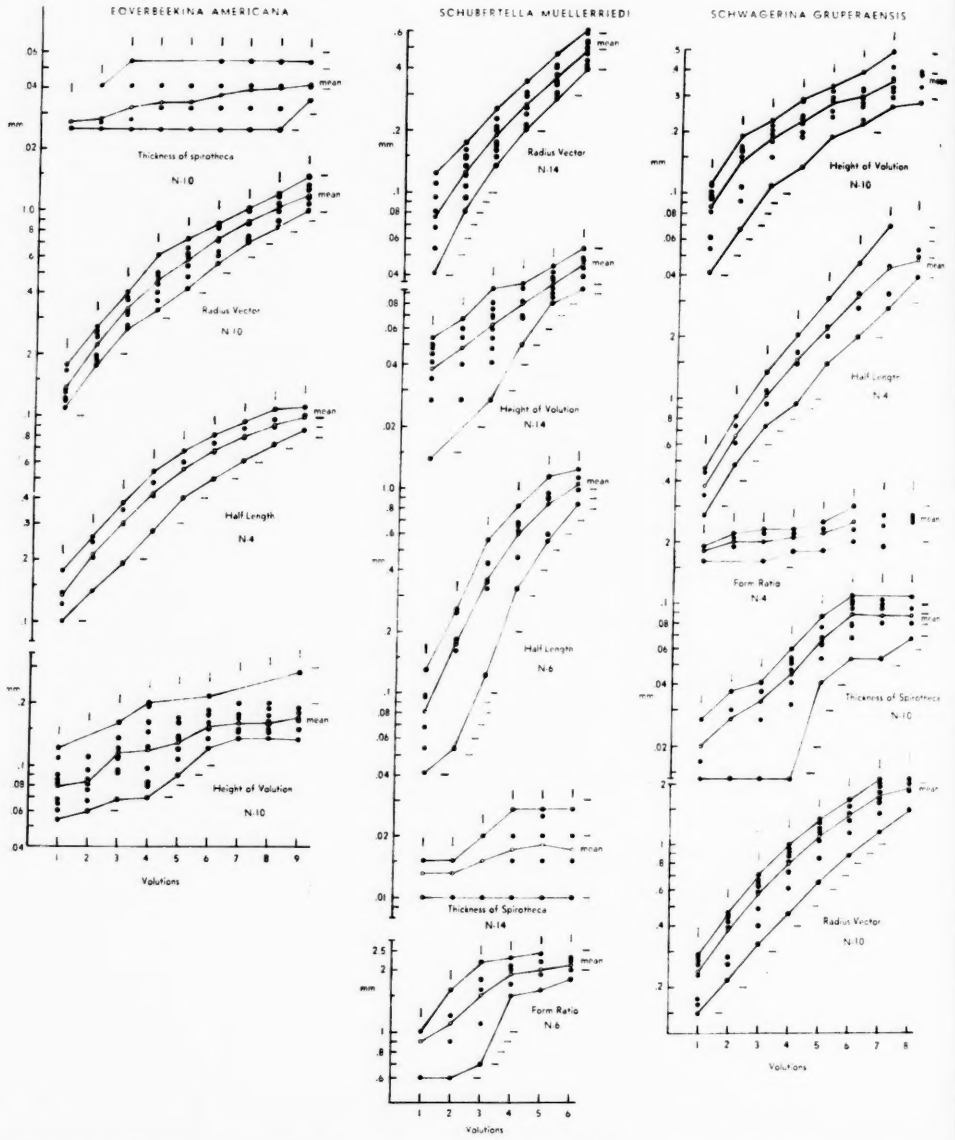
Parafusulina guatemalaensis DUNBAR (1939), (1939), Jour. Paleontology, v. 13, p. 347, pl. 36, figs. 1–10.

This is a slender species attaining an axial length of 11 to 15 mm. and a sagittal width of 2.5 to 3.5 mm. Poles of the inner volutions are rather sharply pointed, but those of the outer two volutions tend to be somewhat rounded, caused by expansion of the outer volutions toward the poles. Mature specimens consist of six to seven volutions. The axis of coiling is straight in most individuals, slightly curved in a few.

EXPLANATION OF PLATE 82

All figures are ×10

FIGS. 1—*Parafusulina erratoseptata* Kling, n. sp. Axial section, AMNH 28278.
2–5—Parafusulina subrectangularis Kling, n. sp. *2,3,4*, Axial sections; *5*, tangential section; AMNH 28279, 28280, 28281, 28282.



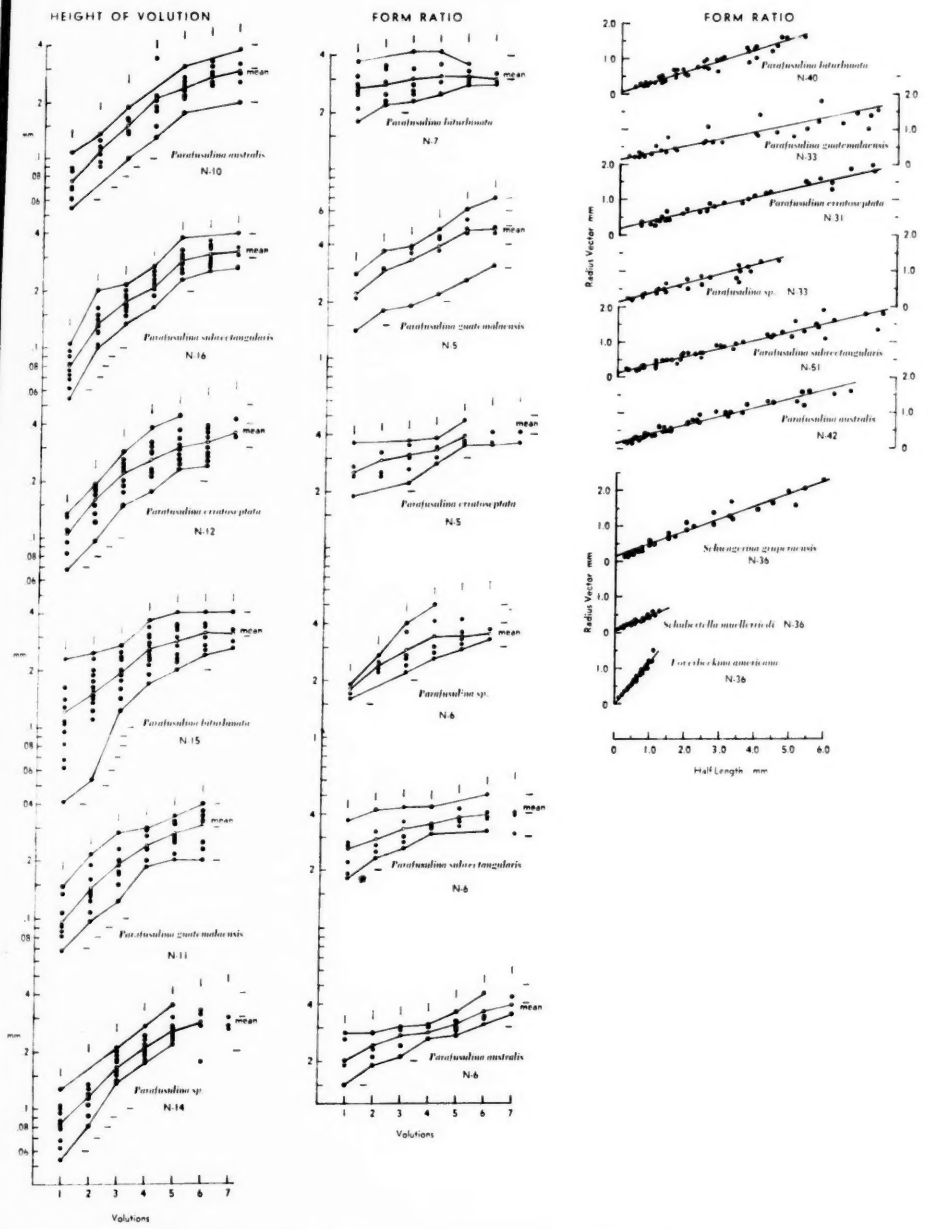
TEXT-FIG. 5—Measurements of wall thickness, radius vector, half-length, volution-height, and form ratio in three species of Guatemalan fusulinids. Minimum, maximum, and mean dimensions are indicated at successive growth stages.

Outside proloculus diameters of 11 specimens range from 270 to 420 microns, averaging 340 microns.

Septa are intensely fluted, and narrow cuniculi can be seen in favorably cut tangential sections. Septal counts of a typical specimen are 13, 20, 28, 28, and 34 for the first through fifth volutions, respectively.

The spirotheca consists of a thin tectum and thick keriotheca. Thicknesses of the combined layers are shown in Text-figure 6.

Tunnel angles range from 34 degrees in the first volution to 44 degrees in the sixth, and increase with reasonable consistency



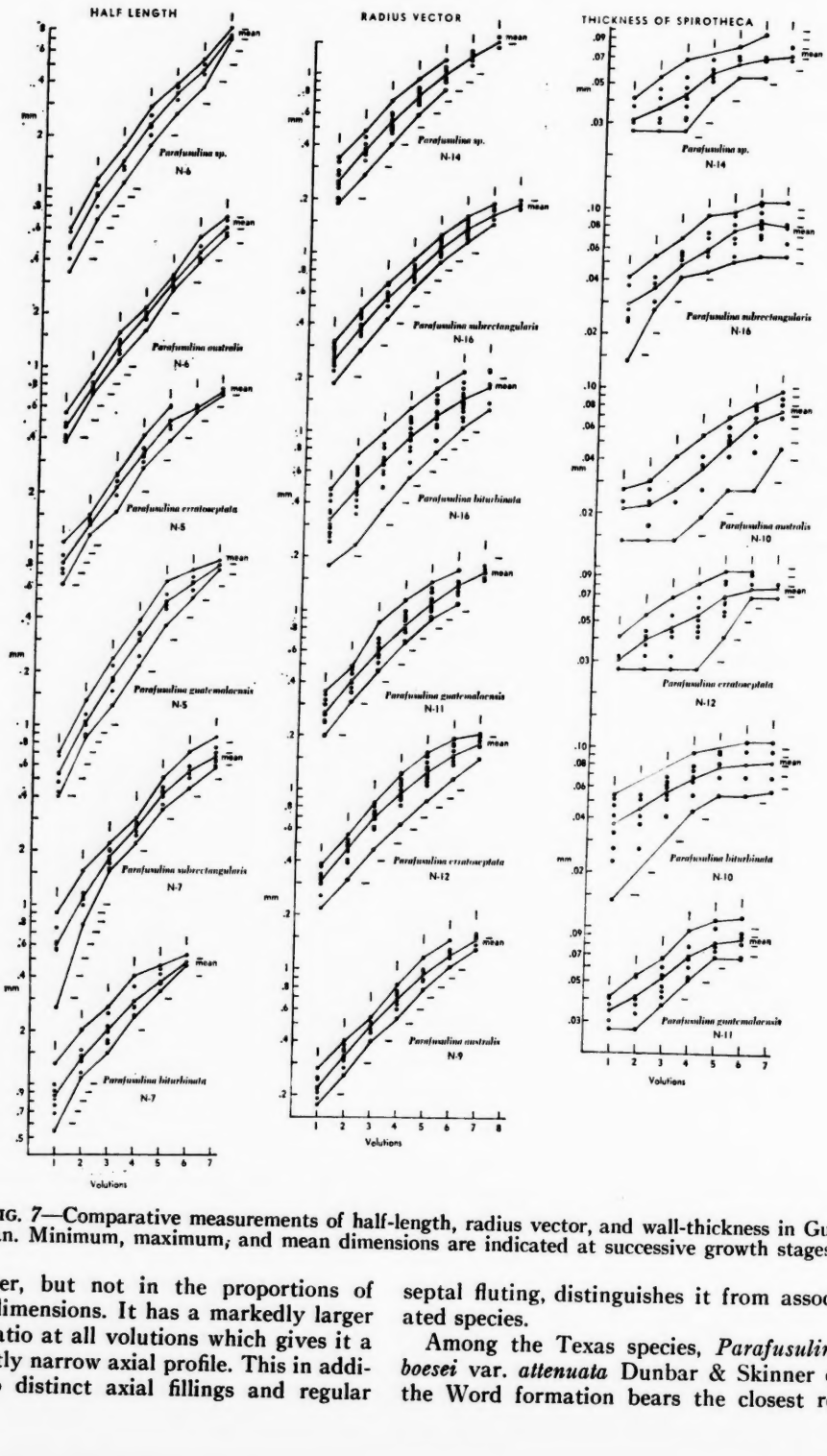
TEXT-FIG. 6—Comparative measurements of volution-height and form ratio in Guatemalan fusulinids. Minimum, maximum, and mean dimensions are indicated at successive growth stages.

during ontogeny.

No chomata have been observed, but a secondary deposit fills the axial regions of the inner three or four volutions. It is generally conspicuous, but not widespread.

Measurements of this species are shown in Text-figures 6 and 7.

Discussion.—This species is similar to several of the other species in this area in dimensions of length, width, and proloculus



TEXT-FIG. 7—Comparative measurements of half-length, radius vector, and wall-thickness in Guatemalan. Minimum, maximum, and mean dimensions are indicated at successive growth stages.

diameter, but not in the proportions of these dimensions. It has a markedly larger form ratio at all volutions which gives it a distinctly narrow axial profile. This in addition to distinct axial fillings and regular septal fluting, distinguishes it from associated species.

Among the Texas species, *Parafusulina boesei* var. *attenuata* Dunbar & Skinner of the Word formation bears the closest re-

semblance to *P. guatemalaensis*. In shape and proportions they are very similar, but the latter has fewer septa, a more conspicuous axial filling, and less advanced septal fluting. The former has, in some cases, a curved axis of coiling not found in the Guatemalan species. There is some similarity also to *P. splendens* Dunbar & Skinner, also of the Word formation, which has a much longer axis than *P. guatemalaensis*, a considerably smaller proloculus, and more intense and regular septal fluting. Thompson & Miller have also pointed out a resemblance between *P. guatemalaensis* and *P. bakeri* of the Leonard formation and *P. fountaini* Dunbar & Skinner of the Bone Spring formation (Leonardian). No additional relationships have been discovered and those that exist are not close enough to warrant restatement here.

Occurrence.—*Parafusulina guatemalaensis* is common in the upper part of the Chochal limestone at Purulhá, Guatemala.

PARAFUSULINA BITURBINATA Kling, n. sp.
Pl. 81, figs. 4, 5, 7–9

This species is one of the smallest in the genus. Mature specimens have a length of from 9 to in excess of 11 mm. with a width of 2 to 4 mm. and consist of five or six volutions. In axial section, the profile describes two uninterrupted arcs tapering from the center with convex lateral slopes to sharply pointed poles. The early volutions are similar in shape to the later volutions, so that the height of a given volution remains about the same throughout the length of the shell. The axis of coiling is essentially straight.

The proloculus is conspicuously large for so small a test. The outside diameters of 17 specimens ranged from 310 to 540 microns, averaging 393 microns.

The septa are intensely and regularly fluted, with high and narrow septal loops showing in axial sections. Tangential sections exhibit well-developed cuniculi. Septal counts average 13, 23, 26, 32, 34, and 38 for the first through sixth volutions, respectively.

The spirotheca consists of a thin tectum and coarsely alveolar keriotheca. Thicknesses of the combined layers are shown in Text-figure 6.

Tunnel angles range from 32 degrees in the first volution to 47 degrees in the fifth volution and show a tendency to increase progressively during ontogeny.

Chomata are not observed in the specimens, but a dense secondary deposit fills a narrow axial zone of the inner three to four volutions.

Measurements of this species are shown in Text-figures 6 and 7.

Discussion.—This species is similar in size and shape to some of the figured specimens of *Parafusulina boesei* Dunbar & Skinner of the Word formation of Texas. However, the outer volutions of the latter species tend to expand toward the poles, which are more rounded, giving it a more cylindrical shape than *P. biturbinata*. In *P. boesei*, the tunnel angle increases more rapidly and the secondary deposits are differently distributed. There is also a resemblance to *P. splendens* Dunbar & Skinner of the Word formation of Texas, but that species has a much larger and more slender test, and a smaller proloculus. *P. biturbinata* is much shorter than *P. guatemalaensis* and has a larger form ratio.

The distinctive features of this species are its nearly perfect fusiform shape, small size, and comparatively large proloculus.

Occurrence.—*Parafusulina biturbinata* is common near the top of the Chochal limestone at Purulhá, Guatemala.

PARAFUSULINA ERRATOSEPTATA Kling, n. sp.
Pl. 80, figs. 4–6; Pl. 82, fig. 1

Description.—This is an elongate, fusiform species usually with curved axis of coiling. Well-oriented axial sections seem consistently to measure 13.5 mm. in length and 3.8 mm. in width though some variation about these values is to be expected. Mature specimens consist of six to seven volutions. Lateral slopes are straight or occasionally slightly convex and descend from nearly the center of the test to rather sharply pointed poles. Volutions are all of the same general shape with little tendency for outer volutions to expand poleward.

Outside diameters of the proloculi of 16 specimens ranged from 310 to 515 microns, averaging 392 microns.

The septa are intensely but distinctly irregularly fluted. Adjacent septal loops are not of uniform width or height. Tangential sections show well-developed cuniculi.

The spirotheca consists of a thin tectum

and thicker keriotheca with distinct alveoli. Thicknesses of the combined layers is shown in Text-figure 6.

Tunnel angles range from 35 degrees in the second volution to 40 degrees in the sixth and show some tendency to increase during ontogeny.

No chomata have been observed. Typically, specimens contain little secondary deposit. In some there is a distinct deposit in the axial regions of the inner two or three volutions.

Measurements of this species are shown in Text-figures 6 and 7.

Discussion.—The size and form ratio of this species fall within the range of the associated species, *Parafusulina biturbinata* and *P. guatemalaensis.* However, general shape, curved axis of coiling, and character of the septal fluting should distinguish *P. erratoseptata* from its associated forms. Among the Texas species, *P. erratoseptata* most closely resembles *P. fountaini* of the Bone Spring formation (Leonardian). The latter species is larger, has more volutions, and has more regular septa.

Occurrence.—Parafusulina erratoseptata is common in the upper part of the Chochal limestone at Purulhá.

Parafusulina subrectangularis
Kling, n. sp.
Pl. 82, figs. 2–5

Mature individuals of this species consist of seven to eight volutions, attain a length of from 13 to 17 mm., and a width of 3 to 5 mm. Early volutions are distinctly elongate with sharply rounded poles, but the outer three volutions become greatly expanded at the poles which are bluntly rounded to nearly rectangular. This results in a subrectangular axial profile in the mature specimens. Since it occurs only in the outer volutions, this rather unusual shape is lost in specimens abraded at the ends. The axis of coiling is straight.

Outside proloculus diameters of 19 specimens range from 245 to 435 microns, averaging 334 microns.

Septal counts for three specimens average 12, 22, 25, 28, 32, and 34 for the first through sixth volutions, respectively. The septa are regularly and intensely fluted. Closely spaced, high septal loops are seen in the inner and middle volutions, but often fail to appear in the outer volutions because the septa are widely spaced. Well-developed cuniculi can be observed in tangential sections.

The spirotheca consists of thin tectum and thick keriotheca with relatively coarse alveoli. Thicknesses of these combined layers are shown in Text-figure 6.

Tunnel angles of five specimens average 34, 37, 35, 36, 39, 48, and 50 degrees, respectively, for the first seven volutions. They show only a slight tendency to increase regularly in succeeding volutions.

No chomata have been observed in these specimens. Secondary deposits are lacking or inconspicuously confined to a narrow axial zone in the inner three or four volutions.

Measurements of this species are shown in Text-figures 6 and 7.

Discussion.—This species appears to be similar in many respects to *Parafusulina sapperi* which has been described from the same general area (Dunbar, 1939). From the published sections and description, it does not seem that these forms are conspecific. *P. sapperi* is somewhat larger with correspondingly fewer volutions, has a larger proloculus, and more conspicuous secondary axial filling.

Parafusulina subrectangularis is similar in shape to *P. sellardsi* of the Word formation of Texas, which has similarly blunt poles in the outer volutions. The latter is, however, larger, has a larger proloculus, and more numerous septa in corresponding volutions.

Distinctive features of this species are its long narrow inner and middle volutions with sharply pointed poles and outer volutions with unusually blunt poles.

Occurrence.—Parafusulina subrectangularis is rare in the middle of the Chochal limestone at Purulhá, Guatemala.

Parafusulina sp.
Pl. 79, figs. 7–10

Members of this group were consistently abraded at both the poles and centers so that a complete axial section with mature volutions intact was not available. In addition, the inner volutions did not appear to resemble those of the other species closely enough to allow a confident specific assignment. The available information is presented here for the sake of completeness.

Inner volutions are elongate and tend to be cylindrical at the center, tapering to narrowly rounded poles. Septa are intensely fluted with high and regularly spaced septal loops. Cuniculi are well-developed. Septal counts average 11, 19, 22, 23, 24, and 31 for the first through sixth volutions in four specimens.

Outside proloculus diameters of 15 individuals ranged from 260 to 405 microns, averaging 328 microns.

Tunnel angles for a typical specimen measured 30, 31, 45, 35, and 42 degrees for the third through seventh volutions, respectively.

No chomata have been observed, but a dense secondary deposit fills the axial regions of the first four volutions and spreads to the borders of the tunnel of the first two volutions.

Measurements of these specimens are shown in Text-figures 6 and 7.

Discussion.—These forms resemble *Parafusulina subrectangularis* in general appearance, but they tend to be more inflated in the equatorial regions and therefore less elongate. Also, a conspicuous axial filling is lacking in *P. subrectangularis*. *P. australis* has similarly shaped volutions and a similar axial filling, but is considerably smaller with a smaller proloculus. *P. guatemalaensis* is much narrower than the specimens discussed here. It is possible, if all the volutions could be seen, that an assignment to *P. sapperi* would be warranted, but the proloculi, which can be measured accurately, are consistently smaller than those reported in *P. sapperi*.

Occurrence.—These specimens occur in the middle part of the Chochal limestone.

REFERENCES

BURMA, B., 1942, Missourian *Triticites* of the northern midcontinent: Jour. Paleontology, v. 16, p. 739–755.

COOGAN, A. H., 1958, Groups of species within *Parafusulina* and their phyletic significance [abstract]: Geol. Soc. America, Bull., v. 69, p. 1548.

DIXON, C. G., 1956, Geology of southern British Honduras: Government Printer, Belize, B. H., 85 p.

DOLLFUS, A. & MONT-SERRAT, E. DE, 1868, Voyage géologique dans les Républiques de Guatemala et de Salvador: (France) Mission Scientifique au Mexique et dansl'Amerique Centrale, Géologie, p. 1–539.

DUNBAR, C. O., 1939a, Permian fusulines from Central America: Jour. Paleontology, v. 13, p. 344–348,

——, 1954, A new technique for making sections of invertebrate fossils: Jour. Paleontology, v. 28, p. 112.

DUNBAR, C. O. & HENBEST, L. G., 1942, Pennsylsylvanian fusulines of Illinois: Illinois Geol. Surv., Bull. 70, p. 1–218.

DUNBAR, C. O. & SKINNER, J. W., 1937, The geology of Texas. Vol. III, Part 2. Permian Fusulinidae of Texas: Univ. Texas Bull. 3701, p. 517–825.

IMBRIE, J., 1956, Biometrical methods in the study of invertebrate fossils: Am. Mus. Nat. Hist., Bull., v. 108, Art. 2, 252 p.

KING, R. E., DUNBAR, C. O., CLOUD, P. E., JR. & MILLER, A. K., 1944, Geology and paleontology of the Permian area northwest of Las Delicias, Southwestern Coahuila, Mexico: Geol. Soc. America, Spec. Paper 52, 172 p.

MORIKAWA, R., 1955, *Schwagerininae* in the vicinity of the Shomaru Pass, Eastern part of Kanto Mountainland, Central Japan: Sci. Rep't Saitama Univ., Ser. B, Vol. II, no. 1, p. 61.

NEWELL, N. D., RIGBY, J. K., FISCHER, A. G., WHITEMAN, A. J., HICKOX, J. E. & BRADLEY, J. S., 1953, The Permian Reef complex of the Guadalupe Mountains region, Texas and New Mexico: A study in paleoecology: Freeman, San Francisco.

ROBERTS, R. S. & IRVING, E. M., 1957, Mineral Deposits of Central America: U. S. Geol. Surv., Bull. 1034, p. 1–201.

SAPPER, K., 1896b, Geology of Chiapas, Tabasco, and the Peninsula of Yucatan: Jour. Geology, v. 4, p. 938–947.

——, 1899, Über gebirgsbau und boden die Nordlichen Mittel Amerika: Petermanns Mitt., no. 127, p. 1–119.

——, 1906, Über gebirgsbau und boden des Südlichen Mittel Amerika: Petermanns Mitt., no. 151, p. 1–82.

——, 1927, Vulkankunde: Stuttgart, Engelborns.

——, 1937, Mittel Amerika, unter mitarbeit von privatdozent Dr. Walther Staub, Bern: Handbuch Region. Geol. Band 8, Abt. 4a, Heft. 29, p. 1–160.

SCHUCHERT, C., 1935, Historical geology of the Antillian-Caribbean region: John Wiley & Sons, New York, 811 p.

STERNBERG, R. M. & BELDING, H. F., 1942, Dry peel technique: Jour. Paleontology, v. 16, p. 135–136.

THOMPSON, M. L., 1948, Studies of American fusulinids: Univ. Kansas Paleont. Contrib., Protozoa, Art. 1, p. 1–184.

THOMPSON, M. L., 1954, American Wolfcampian fusulinids: Univ. Kansas Paleont. Contrib., Protozoa, Art. 5, p. 1–226.

THOMPSON, M. L. & MILLER, A. K., 1944, The Permian of southernmost Mexico and its fusulinid faunas: Jour. Paleontology, v. 18, p. 481–504.

THOMPSON, M. L., WHEELER, H. E., & HAZZARD, J. C., 1946, Permian fusulinids of California: Geol. Soc. America, Mem. 17, p. 1–77.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 656–670, 11 TEXT-FIGS., JULY, 1960

THE PENNSYLVANIAN OSTRACODE *BAIRDIA OKLAHOMAENSIS* IN INDIANA

ROBERT H. SHAVER
Indiana Geological Survey, Bloomington

ABSTRACT—A historical review of the ostracode *Bairdia oklahomaensis, s. l.*, recalls that the species is especially common among Pennsylvanian faunas of the Illinois Basin and the midcontinent but that many concepts under at least four names have been applied to this species. Earlier confusion resulting from the traditional typological approach to *Bairdia* does not permit us to accept safely any concept except the all-inclusive one. The species, therefore, had been assigned a very long range, Morrow into Missouri, and had little or no stratigraphic value.

The triangular graph is a useful tool for the interpretation of a quantitative study of 12 populations of *Bairdia oklahomaensis, s. l.*, from throughout the vertical and lateral range of this species in Indiana. Vertical speciation occurred, and so *B. oklahomaensis, s. s.*, and *B. dornickhillensis* are recognized separately with respective ages of post-Atoka and pre-Des Moines and with further refinements in each of their stratigraphic ranges. *B. auricula* and *B. seminalis* (Payne only) should be considered as synonyms of *B. oklahomaensis, s. s.* Geographic speciation or subspeciation apparently did not occur within the broader concept of the species. The triangular graph shows further that the considerably different mean sizes among the several populations are of no genetic or taxonomic significance.

The ontogeny of *Bairdia oklahomaensis*, with nine molt stages, does not differ importantly from that of modern species of *Bairdia*. The more recent name *Nesidea*, sometimes substituted for *Bairdia*, should be considered as a synonym.

INTRODUCTION

THE ostracode genus *Bairdia* McCoy (1844) ranges from Ordovician to Recent, and it has several hundred species whose intergradations apparently are endless. *Bairdia* dominates many upper Paleozoic ostracode faunas. For example, it comprises 41 of 300 species in Cooper's (1946) "Pennsylvanian ostracodes of Illinois" in which 47 genera are described.

Most Paleozoic bairdiids lack ornamentation which could be used for differentiation; the muscle scar, hinge, and the internal marginal structures changed little through geologic time. Consequently, authors use mostly size, shape, and valve overlap for species differentiation. Many of these species have complicated synonymies, as authors have accorded varying degrees of importance to both minute and large differences in these three features. Neither the stratigraphic nor biologic significance of these differences is commonly known, whether a described species spans the greater part of a system or is known from a single horizon.

For the reasons mentioned above, paleontologists now attach slight value to species of *Bairdia*, and herein lies a paradox. The dominance of ostracode faunas by *Bairdia* in many parts of the geologic column should contribute toward its greater use. It is considered here that we must use methods other than the classic typological analysis in order to recognize phyletic lines that surely will out-perform the traditional index species.

My purpose is to apply quantitative methods of study to the Pennsylvanian species, *Bairdia oklahomaensis, s. l.*, in order to note any directional development through time, to note the ontogenetic development, to assess any stratigraphic significance, and to evaluate the earlier species concepts.

The traditional approaches to this broad group, which ranges through most of the Pennsylvanian system, do not appear to offer any species concept that we may accept safely except possibly the all-inclusive one. Earlier concepts agree at least tacitly, however, on two points. These ostracodes have parallel sides centrally in dorsal view. In lateral view they have prominent angles posteriorly in the dorsal border and in the dorsal line of commissure, with corresponding characteristic over-reach of the right valve by the left (Text-fig. 11). My concept

of *Bairdia oklahomaensis, s. l.*, is objectively morphological to the extent that it requires these features among otherwise rather common characteristics of the genus. I hope to show, however, that for the most useful species we need more than my broad morphological concept in itself or more than the more arbitrary morphological concepts that have evolved.

Statisticians among paleontologists are not overly popular. I agree that many of the classic examples of quantitative species must be considered as academic. The materials used were exceptional, and some studies involved hundreds, even thousands, of specimens of one species. Sylvester-Bradley (1958) emphasized that this kind of study is impractical for the practicing paleontologist when it is applied with classic rigor; nevertheless, he showed, in my opinion, that paleontologists can make practical quantitative treatments of many fossil populations. Shaver (1958) believed that specific small numbers of specimens can result in useful quantitative concepts of ostracodes. The present study deals with only 8 to 30 specimens of *Bairdia oklahomaensis, s. l.*, from each of 12 of the better samples that were taken from a general collection of Pennsylvanian ostracodes of Indiana. No effort was made to secure specimens in greater numbers than those ordinarily obtained from 3 or 4 pounds of rock. The ontogenetic study was made of 96 specimens from the Lonsdale limestone of Illinois.

My thanks are due H. H. Gray and T. G. Perry who critically read the manuscript. This paper is published by permission of the State Geologist, Indiana Department of Conservation, Geological Survey.

SHORT HISTORY OF *BAIRDIA OKLAHOMAENSIS, s. l.*

Harlton (1927) introduced the species *Bairdia oklahomaensis* for ostracodes of late Des Moines age from the Ardmore Basin; he illustrated the characteristic posterior hump in the dorsal border and corresponding uneven over-reach by the left valve. Knight (1928) introduced the name *B. auricula* for similar bairdiids from middle Des Moines rocks in Missouri without comparison with *B. oklahomaensis;* Harlton (1929a) made *B. auricula* a synonym of *B. oklahomaensis.* Harlton (1929b) later drew attention to the parallel sides in dorsal view of *B. oklahomaensis, s. l.*, by noting that the width of his new species at that time, *B. dornickhillensis* from the Morrow Series of Oklahoma, could be measured through a zone rather than along a single line.

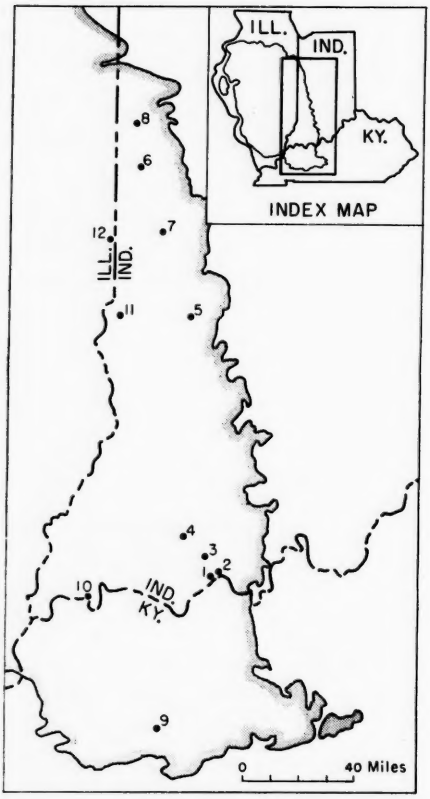
Warthin (1930) placed *Bairdia dornickhillensis* in synonymy with *B. auricula* but recognized the latter separately from *B. oklahomaensis* on the basis of width. Warthin's *B. auricula* and *B. oklahomaensis* are from the upper part of the Des Moines Series of Oklahoma. Coryell & Sample (1932) also recognized these two species separately on the basis of elongation and positions of greatest height and overlap. Both of their species are from one location and horizon in the upper part of the Des Moines Series of Texas. Bradfield (1935) recognized the three species as distinct but with overlapping and partly overlapping Des Moines and Missouri ranges in Oklahoma. Bradfield distinguished his contemporaneous examples of *B. oklahomaensis* and *B. auricula* on the basis of position of the highest point on the dorsal line of commissure.

Johnson (1936) equated the three names and assigned a range of Morrow through Missouri to *Bardia oklahomaensis.* Payne (1937) assigned upper Des Moines specimens of *B. oklahomaensis* from Indiana to *B. seminalis* Knight. Cooper (1946) equated the three species and *B. seminalis* of Payne and assigned a range of Morrow into Missouri to *B. oklahomaensis* from the Illinois Basin. McLaughlin (1952) concurred with this range and described the species from Des Moines or lower rocks in Colorado.

Cordell (1952) equated only *Bardia oklahomaensis* and *B. auricula* and thereby recognized a Des Moines-Missouri range in Missouri. Shaver in Thompson, Shaver & Riggs (1959) recognized *B. dornickhillensis* as a distinct species in a lower Pennsylvanian limestone at Morgantown, Kentucky.

SAMPLES, LOCALITIES, AND STRATIGRAPHY

1. (*Field no. 10-1*).—Six inches of gray shale below 10 inches of black shaly limestone (Fulda limestone?) on the west side



TEXT-FIG. *1*—Map showing location of numbered sample sites in the Illinois Basin (stippled outline).

of a county roadcut in the Ohio River bluff, E½, NW¼, sec. 20, T. 6 S., R. 4 W., Spencer County, Indiana (Text-fig. 1). The sample comes from 20 feet below a higher limestone identified as Ferdinand by Cooper (1946, p. 35, loc. 2), who assigned a Morrow age to the Fulda. The sampled stratum is correlated with an upper part of the Mansfield formation in Indiana and with part of the Lead Creek limestone of Crider (1913) in Kentucky. Specimens catalogued as InGS 322.

2. (*Field no. 16-1, 2*).—Uppermost 21 inches of 2.4 feet of gray shale and shaly limestone near the bottom of the clay pit on the east side of the county road, SW¼, NW¼, sec. 9, T. 6 S., R. 4 W., Spencer County, Indiana. The sampled unit is 13.3 feet below the chert of the Ferdinand limestone. InGS 323.

3. (*Field no. 13-3*).—Ten inches of dark shale above the limestone that is above the Buffaloville coal in the strip pit on both sides of the county road, NE¼, NW¼, sec. 9, T. 5 S., R. 5 W., Spencer County, Indiana. The limestone is in the Brazil formation and is correlated with some of the exposures referred to the Minshall limestone of common usage. InGS 324.

4. (*Ind. Geol. Survey Drill Hole 43*).—Shaly limestone above the Buffaloville coal at a depth of 170.6 to 175.3 feet on the Underhill farm, NE¼, SW¼, sec. 5, T. 4 S., R. 6 W., Warrick County, Indiana. InGS 325.

5. (*Field no. 30-4*).—One foot of dark shale below an unnamed limestone member (Brazil formation), in the Commodore mine, SW¼, SW¼, sec. 2, T. 9 N., R. 6 W., Owen County, Indiana. It is one of the several limestones referred to the Minshall limestone of common usage and is correlated with the limestone above the Buffaloville coal (localities 3 and 4). In GS 326.

6. (*Field no. 50-2*).—A two inch black shale parting, 2.7 feet above the base of 11.3 feet of limestone, in the lower part of the Staunton formation (lower Des Moines) on the east bank of Mill Creek north of the iron bridge, SE¼, NE¼, sec. 28, T. 18 N., R. 8 W., Fountain County, Indiana. Alexander (1943) referred the exposure to the Minshall limestone, but the Indiana Geological Survey now considers it to be one of a number of unnamed limestones in the lower part of the Staunton formation. InGS 327.

7. (*Field no. 46-6*).—Ten inches of shaly limestone from the middle of 3.4 feet of limestone, from the lower part of the Staunton formation, in the strip pit east of the county road at Minshall, SE¼, SE¼, sec. 7, T. 14 N., R. 7 W., Parke County, Indiana. InGS 328.

8. (*Field no. 76-1*).—Four inches of drab shale below approximately 6 feet of limestone on the west bank of a small stream north of Indiana Highway 63, SE¼, NE¼, sec. 2, T. 20 N., R. 9 W., Warren County, Indiana. The limestone is one of those referred to the Minshall limestone of common usage, but the fusulinids *Fusilina* and *Wedekindellina* (M. L. Thompson, oral communication) show that it is of Des

Moines age (probably a limestone in the Staunton formation). InGS 329.

9. (*Field no. 19-1*).—Four inches of dark shale above the Providence limestone in the Grahm quarry of the Duncan Coal Co., 6 miles west of Greenville and 1.1 miles north of U. S. Highway 62, Muhlenberg County, Kentucky. Wanless and Siever (1956, pl. 1) placed the Providence limestone low in the upper part of the Des Moines series. InGS 330.

10. (*Field no. 22-1*).—Three inches of black shale parting, 1.5 feet below the top of the lower limestone of the West Franklin limestone (uppermost Des Moines?), in the Ohio River bluff, 0.3 mile east of West Franklin, SE¼, SW¼, sec. 24, T. 7 S., R. 12 W., Posey County, Indiana. InGS 331.

11. (*Field no. 55-1*).—Six inches of shaly limestone at base of the Vigo limestone member (uppermost Des Moines?) on the south bank of Prairie Creek, 0.2 mile south of Vigo, NE¼, sec. 29, T. 10 N., R. 10 W., Vigo County, Indiana. Waddell (1954) considered the Vigo as part of the Shelburn formation, but the Indiana Geological Survey now places it at about the position of the West Franklin limestone and possibly higher. InGS 332.

12. (*Field no. 61-2*).—Six inches of dark shaly fossiliferous limestone, 5.5 feet above 1.5 feet of brown rubbly limestone on the south bank of Coal Creek, NW¼, sec. 28, T. 14 N., R. 10 W., Edgar County, Illinois. Kosanke (1950) evidently referred the same outcrop to the Brouillet cyclothem (upper Des Moines). Some stratigraphers correlate the limestones of this cyclothem with the West Franklin of Indiana (Weller, in Cooper, 1946, p. 12). InGS 333.

QUANTITATIVE ANALYSIS

Table 1 (page 667) records measurements of 188 specimens of *Bairdia oklahomaensis, s. l.*, from 12 samples and eight or more levels. These data show that a single population, so far as its nature is revealed by the sample, has considerable range in individual size. For example, the adults of sample 6 are between 1.12 and 1.29 mm. long, and the range is 14 percent of the mean; these same adults are between 0.62 and 0.79 mm. high, and the range is 25 percent of the mean. Similar wide ranges are found in the form ratios.

We may ask what is the significance of the statement of dimensions or form ratios of one or two type specimens as is given commonly with the traditional diagnosis of an ostracode. The variations among one population and the wide differences between various populations (Table 2) show that all earlier measurements of one or two specimens of *Bairdia oklahomaensis* contribute little to the determination of useful species.

How many specimens must a sample contain, then, in order to assess the significance of size differences among fossil ostracode populations that are separated by time and space? We may ignore the fact that paleontological samples are not truly representative of original populations; the same argument may be used with greater force against the type method of analysis. The number of specimens required for derivation of reliable mean dimensions is a function of the variation within the population. Each species of ostracode may have its own characteristic magnitude of variation and should be judged individually. Statistical formulae which may be applied to ostracodes for this purpose were used by Shaver (1958), and they are shown in Table 3. He found, for example, that 15 and 6 specimens of *Pseudobythocypris pediformis* (Knight) were required, respectively, for an acceptable 99 percent probability that observed mean lengths were within 3 and 5 percent of the true means insofar as the observed means are affected by sample size and variation. The same accuracies in heights required 29 and 10 specimens.

In order to test the statistical significance of the sizes of samples and means that are recorded in Table 2, standard deviations and standard errors of the means were computed for sample 2 as a general test of reliability. Using these computations, the numbers of specimens that are needed for an acceptable degree of accuracy were computed. Table 3 shows that most of the figures in Table 2 are reliable beyond reasonable doubt with 5 percent error or less. Actually, 10 to 20 specimens are a small number in view of the wide range in a population, and they are commonly available to the paleontologist.

Several questions about the primary data

TABLE 2.—MEAN DIMENSIONS OF ADULT SPECIMENS OF *Bairdia oklahomaensis, s. l.*, FROM TWELVE SAMPLES FROM THE ILLINOIS BASIN, IN APPROXIMATE STRATIGRAPHIC ORDER

Sample	Length		Height		Width		SS′	
	No. of specimens	mm.	No. of specimens	mm.	No. of specimens	mm.	No. of specimens	mm.
12. Brouillet?	13	1.37	13	0.83	13	0.61	12	0.56
11. Vigo	6	1.19	6	0.71	6	0.56	6	0.59
10. West Franklin	12	1.31	12	0.75	10	0.58	12	0.62
9. Providence	10	1.24	12	0.74	10	0.56	10	0.61
8. Staunton	10	1.33	9	0.75	8	0.56	10	0.60
7. Staunton	22	1.29	18	0.73	16	0.56	21	0.67
6. Staunton	17	1.25	20	0.70	11	0.56	13	0.61
5. Brazil	28	1.09	28	0.63	28	0.48	28	0.57
4. Buffaloville	11	1.27	10	0.72	9	0.56	10	0.65
3. Buffaloville	11	1.28	11	0.75	11	0.54	11	0.67
2. Fulda?	23	1.25	23	0.72	15	0.54	21	0.69
1. Fulda?	9	1.25	9	0.73	9	0.56	9	0.72

TABLE 3.—NUMBERS OF ADULT SPECIMENS OF *Bairdia oklahomaensis, s. l.*, IN SAMPLE 2 REQUIRED FOR 99 PERCENT PROBABILITY THAT MEANS ARE ACCURATE WITHIN 3 OR 5 PERCENT

No. specimens observed and dimension	Observed σM†	3 percent		5 percent		Observed σ
		Required σM*	N†	Required σM*	N†	
	(microns)	(microns)		(microns)		(microns)
23 Length	10	13	14	18	8	46
23 Height	8	8	26	12	12	39
15 Width	7	6	19	8	10	25
20 SS′	10	8	29	12	14	42

† N and observed σM computed from:

$$\sigma M = \frac{\sigma}{\sqrt{N-1}},$$

where σM is the standard error of the mean, σ the standard deviation, and N the number of specimens: σ is computed from:

$$\sigma = \sqrt{\frac{\sum d^2}{N-1}},$$

where d is the deviation of an item from the mean.

* For 99 percent probability, required σM computed from:

$$\sigma M = \frac{.03M \text{ or } .05M}{t_N},$$

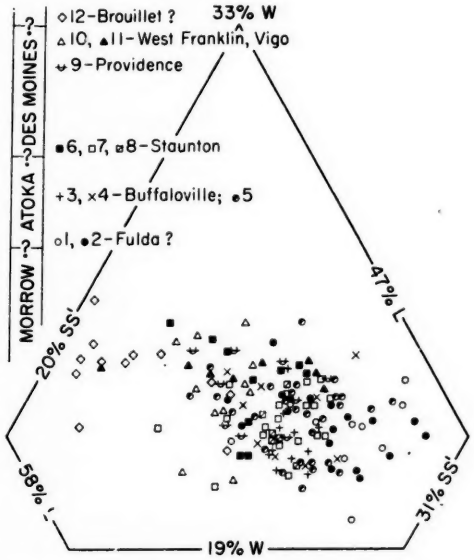
where t_N is a factor that varies with N: if $N = \infty$, $t = 2.576$; if $N = 14$, $t = 3.012$; etc.

of Table 2 remain unanswered. Can species (or subspecies) be recognized in this series that embraces lower to upper? Pennsylvanian rocks? If speciation occurred, were time or geography, or both, the correlative factors? Of what significance is size for recognition of species (subspecies)? Of what value is *Bairdia oklahomaensis, s. l.*, for stratigraphic correlation?

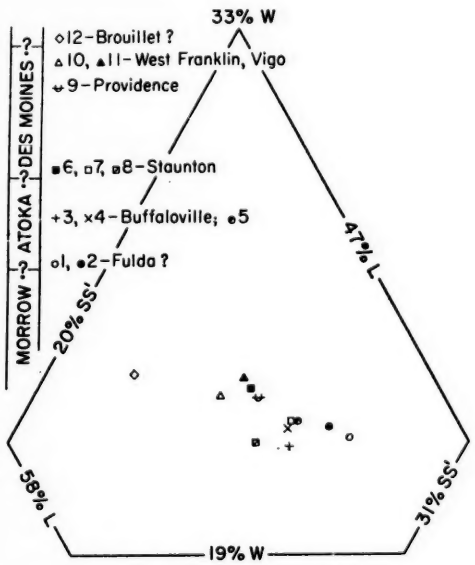
The principal dimensions (Table 2) apparently did not change progressively. Ecological factors may have accounted for the random size differences among the several populations, and size apparently is of no significance for assessing speciation (subspeciation). A fourth dimension, heretofore overlooked, is the length of the central straight segment of the lateral border as seen in dorsal view (SS′). The absolute measure of SS′ generally decreased through time, but its relative value presents a better means of comparison. Therefore, length, width, and SS′ for each specimen were totaled. The total was used as a base for computing the proportion of each dimension, and the proportions then were plotted on triangular graphs. Height also could be used, but a fourth factor greatly complicates the problem of presentation. SS′ could be compared with only one other dimension, length for example, but more factors have greater significance if in fact a species is the total of all of its characters.

The plotted proportions for all specimens from 12 samples (Text-fig. 2) are aligned generally in order of age. The *mean* proportions (Text-fig. 3) show the alignment more clearly. Thus, my basic assumption in the following discussions is that shape is significant but not size, at least not as size is conventionally stated in terms of length, height, and width.

The few paleontologists who have used the triangular graph do not agree on its interpretation. Burma (1948) inferred distinct species from the triangular graphs of the pelecypod *Anthracomya*, because the area for each population, although overlapping that of other populations, is definite in itself. Sylvester-Bradley (1951) inferred several subspecies of one species from the same data because of the overlap in characters. Tasch (1955) agreed with Sylvester-Bradley's interpretation of *Anthracomya*.



TEXT-FIG. 2—Triangular graph for 151 specimens of *Bairdia oklahomaensis, s. l.*, from 12 samples representing as many as 8 Pennsylvanian horizons. L, length; W, width; SS′, distance between shoulders in dorsal view. 5 = unnamed Brazil limestone.



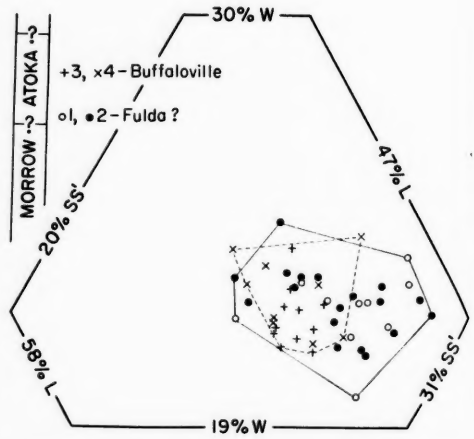
TEXT-FIG. 3—Triangular graph showing the mean proportions for each of 12 samples of *Bairdia oklahomaensis, s. l.*, shown in Text-figure 2. 5 = unnamed Brazil limestone.

He considered that if plots for time-separated populations of a species overlap, vertical subspeciation occurred if the common core does not include the bulk of plotted points. He termed populations differentiated in this way *chronodemes* (Sylvester-Bradley, 1951). Tasch suggested that geographical subspecies (topodemes) could be revealed in the same way if the plots for geographically separated populations from one time horizon overlap, but the bulk of points lies outside the common core. Presumably, speciation occurred if the plots do not overlap. We might choose other arbitrary limits, such as 5 and 25 percent, and assign ranks, but Tasch's recommendation has merit if only to encourage consistent interpretation.

My procedure differs from some precedents on another point of interpretation of the triangular graph. I computed the percentage of overlap of populations by enclosing their areas with straight lines between the outermost points and by making a count of points. I could have interpreted smooth closed curves from a much larger hypothetical sample and either counted points or computed areas of overlap and nonoverlap. The alternative procedure might have resulted in different figures but not in the kind of results.

In the example here, nearly complete transition exists between the 12 populations, but their end members scarcely overlap. We may select pairs of populations and demonstrate subspeciation after the manner of Tasch, and by ignoring the tiny overlap of the end members we could infer distinct species. However, if we consider the intervening populations, even the one and 50 percent application becomes sterile, and division into species or subspecies is arbitrary. Of course, the typological method is inadequate to express this phyletic line in which there are no large gaps, and the subspecies is not immune to this fact.

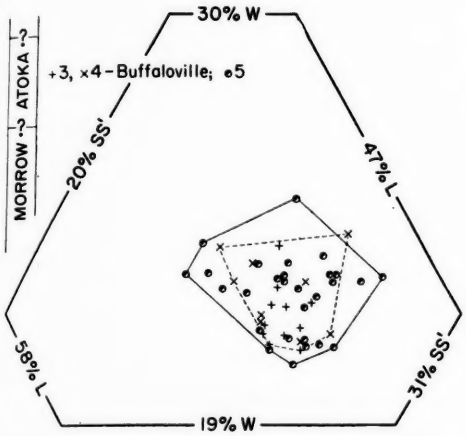
Let us consider the possibility that geographic species (subspecies, topodemes) are indicated. Samples 1 and 2 from the Fulda limestone? appear to be nearly identical (Table 2), as is substantiated by the Fulda portion of Text-figure 4, and geographical speciation (subspeciation) did not occur. Therefore, I have drawn the closed curve



TEXT-FIG. 4—Triangular graph for *Bairdia oklahomaensis, s. l.*, from 4 samples from the Fulda limestone? and limestone above the Buffaloville coal. Percentage of overlap of the two horizons is 54.

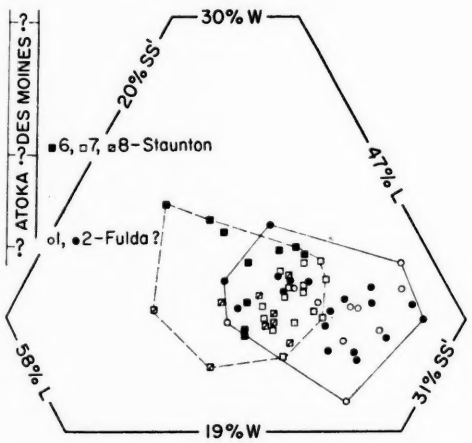
around both plots for the one horizon. The same conclusion results from the plots of samples 3 and 4 (Text-fig. 4). These conclusions are expected because each pair was sampled in a small area. The Brazil and Buffaloville samples, although taken from correlative units, came from well separated localities. The two populations have quite different mean sizes, but Text-figure 5 reduces these differences to their proper importance, and geographical speciation (subspeciation) did not occur. Thus, the size differences among these populations, although probably produced by ecological factors, are without significance to speciation (subspeciation).

The three Staunton samples are not necessarily from one horizon. Their plot (Text-fig. 6) does not occupy a larger area than that of some single populations, and geographical species (subspecies) cannot be inferred unless more definite correlation of the collected strata is made. The West Franklin and Vigo populations came from correlative or very nearly correlative units, and the limestone labeled here as Brouillet? possibly is equivalent. The areas of plots for the West Franklin and Vigo populations (Text-fig. 7) are each elongated in a direction normal to the other, so that most points fall

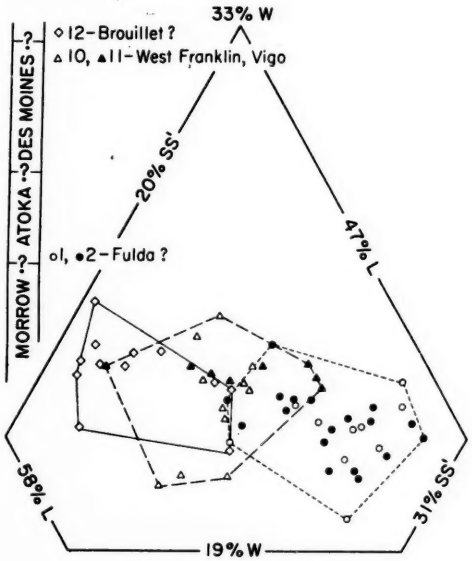


TEXT-FIG. 5—Triangular graph for *Bairdia oklahomaensis, s. l.*, in three populations from two correlative horizons, the limestone above the Buffaloville coal and the Brazil limestone member. Percentage of overlap of the two units is 75. 5 = unnamed Brazil limestone.

outside the small area of overlap. I attach no biological significance to the elongation, and neither of the mean proportions carries farther than the other the trend that was established by older populations. Geographical speciation (subspeciation) would be difficult to assess, and I have chosen to circumscribe



TEXT-FIG. 6—Triangular graph for *Bairdia oklahomaensis, s. l.*, from 5 samples from the Fulda limestone? and limestones in the lower part of the Staunton formation. Percentage of overlap of the two units is 59.

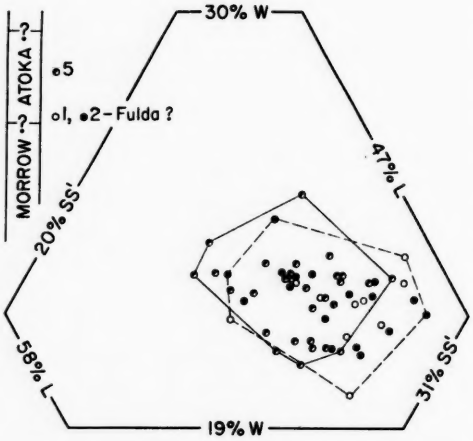


TEXT-FIG. 7—Triangular graph for *Bairdia oklahomaensis, s. l.*, from 5 samples from the Fulda limestone?, West Franklin limestone, and Vigo limestone member. Percentage of overlap for the pairs of horizons: Fulda? and West Franklin-Vigo, 32; Fulda? and Brouillet?, 5; West Franklin-Vigo and Brouillet?, 39.

both populations as one. The Brouillet? population, however, took the earlier established trend to its extreme point, whether it is compared with the West Franklin, Vigo, or combined West Franklin and Vigo populations.

Accepting the stratigraphic correlation, we may here recognize geographical species (subspecies, topodemes). Should we expect geographical speciation (subspeciation) here? I could not demonstrate it with other pairs that are separated by as great distances and that have equally large differences in size. Neither do we know of the barrier presumed necessary. Vertical speciation (subspeciation, chronodemes) remains as a possibility. This interpretation would require that an age younger than that of West Franklin be assigned to the stratum of sample 12, if we project the established trend in the same direction.

If vertical speciation (subspeciation) occurred, on what time-stratigraphic scale can it be observed and applied in the Pennsyl-

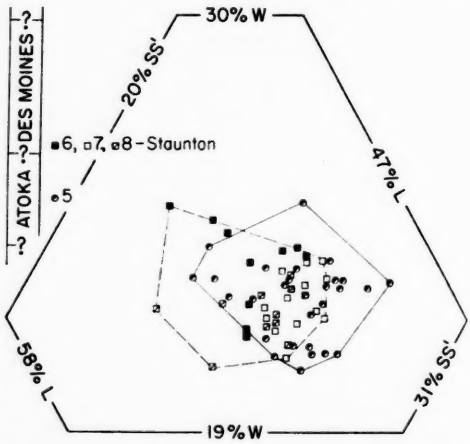


TEXT-FIG. 8—Triangular graph for *Bairdia oklahomaensis, s. l.*, from 3 samples from the Fulda limestone? and unnamed limestone member of the Brazil formation. Percentage of overlap of the two horizons is 71.

vanian strata of Indiana? Text-figures 4 and 8 hardly satisfy Tasch's requirement for subspeciation, but the displacement to the left of the plots of the younger populations appears to be significant. The strata between the Fulda limestone? of the sampled locations and the limestone above the Buffaloville coal have an approximate thickness of 90 feet without known intervening major unconformity. The strata between the Brazil and lower part of the Staunton have an approximate thickness of 75 feet (Text-fig. 9).

The Fulda and Staunton plots (Text-fig. 6) are offset significantly but not enough to infer vertical subspeciation in the prescribed manner. The sampled locations are separated by considerable distance along the strike of outcrop, but the intervening strata have an approximate thickness of 100 feet. The Staunton and West Franklin-Vigo populations if plotted separately would show a similar relationship. The intervening strata have an approximate thickness of 540 feet, and they comprise most of the Des Moines Series. The percentage of overlap of these populations is 63. Vertical subspeciation as prescribed did occur within the time span of the Brazil, Providence, and West Franklin-Vigo populations (see Text-fig. 2). Most of the Des Moines Series intervenes between the Brazil and West Franklin-Vigo populations, but the Brazil and Providence populations are separated by less time and strata. The percentage of overlap of these populations is: Brazil and Providence 42; Brazil and West Franklin-Vigo, 47; Providence and West Franklin-Vigo, 63.

Refinement of these results and similar studies of *Bairdia oklahomaensis, s. l.*, from the midcontinent should reveal additional information on the value of this type of study for interregional correlation. The triangular graph also appears useful here for settling some taxonomic complexities. *B. dornickhillensis*, whose types are of early Pennsylvanian age, may be removed from the synomomy of *B. oklahomaensis, s. s.*, and should be used as the pre-Des Moines species. *B. seminalis* of Payne and *B. auricula*, both of Des Moines age, should be considered as synonyms of *B. oklahomaensis, s. s.* I consider that these ostracodes comprise a completely gradational series and that qualitative criteria may not be used consistently for more arbitrary determinations like those of authors of the reviewed faunal studies. Therefore, I prefer here to assign existing terminology and to avoid new ranks and names which would encounter exactly the same problems of separation as do my more conventional desig-



TEXT-FIG. 9—Triangular graph for *Bairdia oklahomaensis, s. l.*, from 4 samples from the unnamed limestone member of the Brazil formation and limestones in the lower part of the Staunton formation. Percentage of overlap of the two units is 70. 5 = Brazil limestone.

nations. Nor do I consider that new names and ranks would express better the evolutionary development of this group of ostracodes.

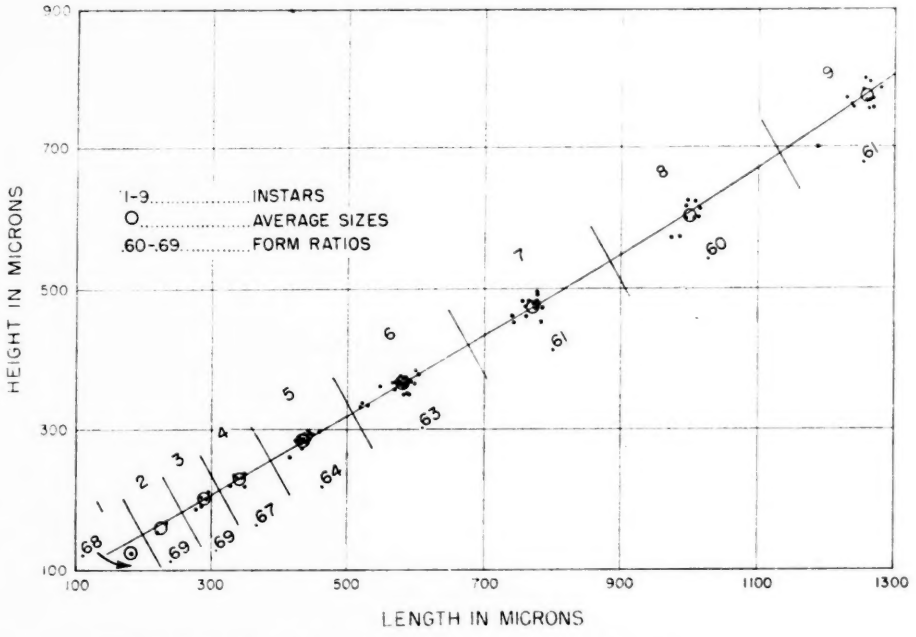
Further application of this study might project the lineage of *Bairdia oklahomaensis, s. l.* into older and younger rocks. *Bairdia golcondensis* and *B. impendere* of Cooper (1947, pl. 21) from the Kinkaid limestone (upper Mississippian of Illinois) have very long parallel sides and appear to fit nicely on the earlier end of our series. *B. granireticulata* Harlton (1929b, pl. 2) from the Fayetteville shale (upper Mississippian of Oklahoma) probably belongs here. Kellett (1935) noted the close resemblance of *B. kanwakensis* from the Kanwaka shale (upper Pennsylvanian of Kansas) and *B. oklahomaensis*. *B. kanwakensis* probably is in the direct line of descendancy at that stage of development that does not have parallel sides in dorsal view.

MOLT STAGES

Beginning with Claus (1872), many neontologists have shown that modern ostracodes of the group Podocopa, including *Bairdia*, have nine molt stages or instars. Little is known of the details of molting of Paleozoic Podocopa. Muller (1894) gave a good account of the molting history of modern *Bairdia*, and Kellett (1934) was the first to devote considerable attention to the juvenile stages of fossil *Bairdia*. She noted the apparent lack of duplicature, the more pointed ends, the narrower dorsal overlap, and the greater elongation of the young of some species.

This study deals with the molt stages of *Bairdia oklahomaensis* from the shale below the lower bench of Lonsdale limestone, SE¼, sec. 16, T. 12 N., R. 9 E., Marshall County, Illinois (Cooper, 1946, loc. 62). The specimens are deposited at the University of Illinois.

Lengths and heights of 96 specimens of all sizes found are shown in Text-figure 10. The nine groups of points show that Paleozoic *Bairdia* had at least nine stages as its modern counterpart does. Some of the growth relationships of ontogeny are recorded in Table 4. A figure of 18 for the percent of

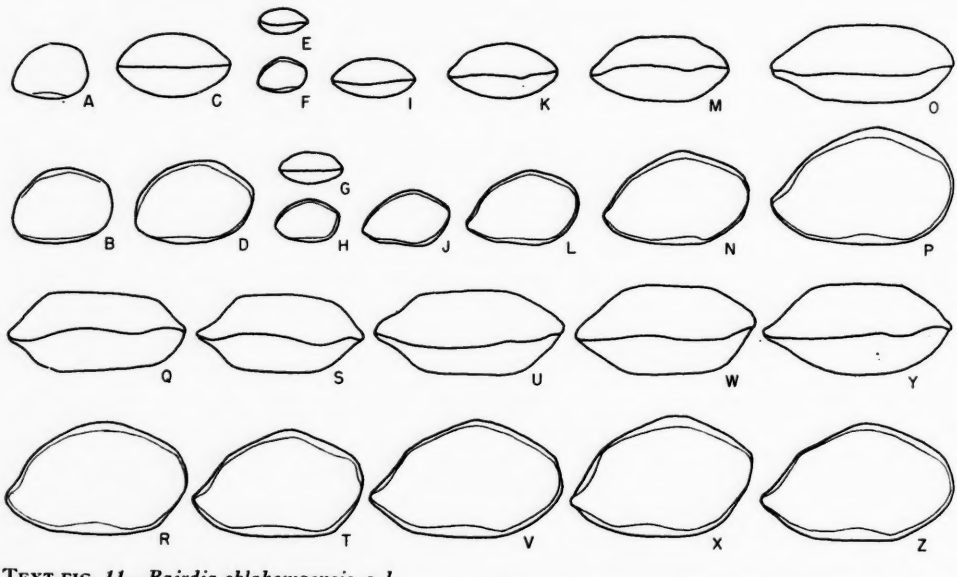


TEXT-FIG. *10*—Graph showing size distribution of 96 specimens of *Bairdia oklahomaensis, s. s.*, from the Lonsdale limestone, Marshall County, Illinois.

TABLE 4.—SIZE RELATIONSHIPS OF THE MOLT STAGES OF *B. oklahomaensis*

Instar and no. of specimens	Length			Height	
	Average (mm.)	Percent of increase	Percent of adult length	Average (mm.)	Percent of increase
9–13	1.26	26	100	0.77	28
8–9	1.00	30	80	0.60	28
7–14	0.77	32	61	0.47	29
6–29	0.58	33	46	0.37	30
5–17	0.44	29	35	0.28	25
4–6	0.34	20	27	0.23	17
3–5	0.28	23	22	0.20	22
2–2	0.23	31	18	0.16	30
1–1	0.18		15	0.12	
Average growth factor		1.28			1.26

total length attained during the second instar is exactly the same as that for the specimen of modern *B. serrata* figured for the second instar by Muller. Furthermore, a figure of 15 percent for instar 1 is smaller than the figures for the corresponding instars of other published Paleozoic ontogenies, including 23 percent for *Ectodemites plummeri* (Cooper, 1945) and 24 percent for a species of *Cavellinidae* (Shaver, 1953). Therefore, probably no more than nine stages existed for Paleozoic *Bairdia*.



TEXT-FIG. *11—Bairdia oklahomaensis, s. l.*

A–P. *B. oklahomaensis, s. s.*, molt series, Lonsdale limestone, Marshall County, Illinois; A,B, right valve views of instars 1 and 2, ×57; C,D, dorsal and right valve views of instar 3, ×57; E-P, dorsal and right valve views of instars 4–9, ×20.

Q–T. *B. dornickhillensis*; dorsal and right valve views of 2 adults, ×20, respectively from the Fulda limestone, locality 1 and unnamed limestone member of the Brazil formation, locality 5.

U–Z. *B. oklahomaensis, s. s.*, dorsal and right valve views of 3 adults, ×20, respectively from a limestone in the lower part of the Staunton formation, locality 8, the West Franklin limestone, locality 10, and a limestone of the Brouillet cyclothem, locality 12.

Bairdia oklahomaensis had an average growth factor of 1.28 for length and 1.26 for height; both figures are close to Przibram's (1931) factor of 1.26 that he applied to modern Arthropoda. The different factors for length and height correspond to elongation of the carapace during growth (contrary to Kellett's observation). This kind of growth is termed *allometric* (Imbrie, 1956), but a slight reversal of the trend toward elongation occurred with the adult stage. The carapacic growth habits no doubt were related to the addition of appendages posteriorly during the juvenile stages and the attainment of sexual maturity during the last stage.

The young have evenly biconvex lateral borders in dorsal view (Text-fig. 11); only the eighth and adult stages have the parallel sides that are an essential character of the species. Similarly, only the specimens of the last two stages generally have slightly concave terminal portions of the lateral borders. In lateral view the borders of the young carapaces are more rounded, and growth was accompanied by increasing bairdian angularity and increasing prominence and elevation of the posterior beak. The calcareous inner lamella, or duplicature, is one of the most important carapacic features of Podocopa, but the duplicature apparently is absent from, or is poorly developed in, all stages except the last two of *Bairdia oklahomaensis*.

These changes during ontogeny affected the essential morphology of various ranks in which the species is classified. Furthermore, there is some evidence that the growth relationships of ontogeny are useful characteristics to taxonomists. However, the ontogeny of *Bairdia oklahomaensis* apparently does not differ significantly from that of modern species of *Bairdia*. This fact and their similar morphologies, which are well known, lead to the conclusion that *Bairdia* attained its principal anatomical and physiological development during the Paleozoic era. Here is additional evidence, then, that bears on the problem of separate recognition of *Bairdia* based on Paleozoic types and *Nesidea* Costa (1849) based on living ostracodes. *Nesidea* should continue to be considered as a synonym of *Bairdia*.

TABLE 1.—DIMENSIONS IN MICRONS OF ALL SPECIMENS OF *Bairdia oklahomaensis*, *s. l*, USED IN THE STUDY UNDER THE HEADING QUANTITATIVE ANALYSIS

Sample No.	Length	Height	Width	SS'†
	1308	793	596	556
	1434	858	626	556
	1343	874	636	505
	1328	707	596	631
	1374	828	606	556
	1464	729	596	707
12	1364	828	611	631
	1399	838	596	525
	1338	793	581	505
	1439	884	571	556
	1338	884	641	
	1364	823	611	556
	1389	768	621	505
	1167	722	545	631
	1222	758	571	606
	1278	793	606	682
11	*1045	591	475	480
	1151	727	556	606
	1172	672	530	556
	*970	606	439	429
	1166	606	510	454
	1293	808	556	606
	1273	773	626	606
	1364	758	646	606
	1338	813		631
	1298	722	606	631
	1328	722		606
10	1237	677	545	556
	1343	813	606	656
	1303	808	591	631
	1328	662	571	631
	1348	737	530	656
	1333	687	515	606
	*990	621	460	429
		692		
	1283	758	606	606
	1116	717	530	606
	1242	762	556	581
	1212	672	520	631
9	1283	798	596	571
	1273	712	540	606
	1212	758		
	1237	707	520	606
	1242	793	591	631
	1257	762	571	656
		758	576	606

† SS' is the distance between shoulders of the larger left valve as seen in dorsal view.

* Immature specimen used in triangular graph but not in computation of mean dimensions shown in Table 2.

(*Table 1 continued on next page*)

TABLE 1.—(*Continued*)

Sample No.	Length	Height	Width	SS'†
	1323	762	561	682
	1379	758	530	656
	1389			
	1318	803	606	682
	1333	656	561	682
8	1293	773	535	682
	1313	732	576	656
	1414	783		707
	*1050	616	429	454
	1333	778	571	682
	1222	692	520	581
	1278	778	535	656
	1338	773	576	707
	1323	717	591	682
	1288	742	586	682
	1247	732	586	656
	1353			707
	1283	667	576	682
	1262	722	596	682
	1328			707
	1247	717	505	656
7	1379			656
	1313			682
	1328	808		
	1262	727	566	656
	1308	808	556	656
	1237	727	562	631
	1273	742	556	697
	1182	682		656
	1278	707	576	606
	1202	702	556	656
	1308	752	562	656
	1212	697	535	656
	1288	631	606	656
	1247	641	586	581
	1187	707	566	505
	1232	656	530	606
	1278	672	606	581
	1237	616	556	581
	1293	656	591	631
	1293	697		
	1283			
6		647		656
	1283	793		
		727		
	1288	717		
	1268	758		
		732		
		758		
	1202	667	571	631
	1273	732	520	631
	1187	758		606
	1121	672	535	581
	1273	707	520	631
	1232	747	586	732
	1050	636	439	581
	1222	727	621	631

TABLE 1.—(*Continued*)

Sample No.	Length	Height	Width	SS'†
	1010	621	470	556
	1050	621	490	606
	1035	611	475	520
	1020	596	444	505
	1030	571	475	411
	1162	631	505	556
	1060	621	485	485
	1040	586	485	576
	1101	667	454	581
	975	616	444	505
5	1162	697	525	606
	1162	712	556	631
	1086	646	505	566
	1071	667	444	581
	1071	641	434	556
	1050	626	439	591
	1025	581	460	556
	1212	687	505	656
	1066	581	480	566
	1262	656	505	677
	1020	591	465	530
	1010	556	439	454
	1030	561	454	480
	1096	641	454	556
	1081	586	475	581
	1222	672	556	606
	1252	656	550	606
	1172	752	581	656
	1262	758	535	707
	1333	722	556	682
4	1182	707	540	556
	1293	762	545	656
	1293			
	1343	762		606
	1313	677	545	707
	1323	697	601	707
	1257	742	556	682
	1227	717	545	631
	1237	707	510	631
	1368	813	556	707
	1227	737	530	631
3	1262	783	515	682
	1313	788	556	707
	1283	737	606	656
	1298	778	560	682
	1283	747	535	656
	1278	752	530	672
	1273	717	535	732
	1328			
	1232	717	566	656
	1227	707	510	682
	1348	808		
	1278	712		732
	1283	656	556	707
	1328	793		
	1288	697		
	*1010	556	444	480

TABLE 1.—(*Continued*)

Sample No.	Length	Height	Width	SS'†
	1303	758	596	758
	1278	707		682
	1222	702	545	631
2	1187	682		656
	1222	667	535	732
		762	510	758
	1227	742		707
	1222	747	510	707
	1197	717		656
	1247	722	581	768
	1232	742	560	641
	1212	732	556	758
	1177	722	550	682
	1232	682	545	682
	*934	581	399	454
	*964	515	470	480
	*990	535	449	505
	1237	651	560	697
	1278	707	576	732
	1303	727	581	707
	1237	732	545	732
	1212	707	545	631
1	1252	707	535	707
	1172	722	556	707
	1262	793	621	758
	1247	722	560	707
	1313	747	510	758
	*995	591	414	480

REFERENCES

ALEXANDER, J. W., 1943, Key beds of Pennsylvanian section of eastern Vermillion County, Illinois, and Vermillion, Warren, and Fountain Counties, Indiana: Illinois Acad. Sci., Trans., v. 36, p. 141–144.

BRADFIELD, H. H., 1935, Pennsylvanian Ostracoda of the Ardmore basin, Oklahoma: Am. Paleontology, Bull., v. 22, no. 73, 173 p., 13 pls.

BURMA, B. H., 1948, Studies in quantitative paleontology: I. Some aspects of the theory and practice of quantitative invertebrate paleontology: Jour. Paleontology, v. 22, p. 725–761.

CLAUS, CARL, 1872, Beiträge zur Kenntniss der Ostracoden, I. Entwicklungsgeschichte von *Cypris:* Schr. Gesell. Naturw. Marburg, Band 9, p. 151–166 (published separately in 1868).

COOPER, C. L., 1945, Moult stages of the Pennsylvanian ostracode *Ectodemites plummeri:* Jour. Paleontology, v. 19, p. 368–375, pl. 57.

——, 1946, Pennsylvanian ostracodes of Illinois: Illinois Geol. Survey, Bull. 70, 177 p., 21 pls.

——, 1947, Upper Kinkaid (Mississippian) microfauna from Johnson County, Illinois: Jour. Paleontology, v. 21, p. 81–94, pls. 19–23.

CORDELL, R. J., 1952, Ostracodes from the upper Pennsylvanian of Missouri. Part I: The family Bairdiidae. Jour. Paleontology, v. 26, p. 74–112, pls. 17–20.

CORYELL, H. N. & SAMPLE, C. H., 1932, Pennsylvanian Ostracoda. A study of the Ostracoda fauna of the East Mountain shale, Mineral Wells formation, Mineral Wells, Texas: Am. Midland Naturalist, v. 13, p. 245–281, pls. 24–26.

COSTA, O. G., 1849, *Nesidea*, nuovo genere di entomostracei dell'ordine degli ostracodi o ciproidi: Accad. pontaniana, Naples, Atti, v. 5, p. 183–188, pl. 4.

CRIDER, A. F., 1913, Economic geology of Tell City and Owensboro quadrangles: Kentucky Geol. Survey, 4th ser., v. 1, pt. 1, p. 262–316.

HARLTON, B. H., 1927, Some Pennsylvanian Ostracoda of the Glenn and Hoxbar formations of southern Oklahoma and of the upper part of the Cisco formation of northern Texas: Jour. Paleontology, v. 1, p. 203–212, pls. 32,33.

——, 1929a, Pennsylvanian Ostracoda from Menard County, Texas: Texas Univ. Bull. 2901, p. 139–161, pls. 1–4.

——, 1929b, Some upper Mississippian (Fayetteville) and lower Pennsylvanian (Wapanucka-Morrow) Ostracoda of Oklahoma and Arkansas: Am. Jour. Sci., v. 18, no. 105, p. 254–270, pls. 1,2.

IMBRIE, JOHN, 1956, Biometrical methods in the study of invertebrate fossils: Am. Mus. Nat. History, Bull., v. 108, p. 215–252.

JOHNSON, W. R., 1936, The Ostracoda of the Missouri series in Nebraska: Nebraska Geol. Survey, Paper 11, 52 p., 5 pls.

KELLETT, BETTY, 1934, Ostracodes from the upper Pennsylvanian and the lower Permian strata of Kansas: II. The genus *Bairdia:* Jour. Paleontology, v. 8, p. 120–138, pls. 14–19.

——, 1935, Ostracodes of the upper Pennsylvanian and the lower Permian strata of Kansas: III. Bairdiidae (concluded), Cytherellidae, Cypridinidae, Entomochonchidae, Cytheridae and Cypridae: Jour. Paleontology, v. 9, p. 132–166, pls. 16–18.

KNIGHT, J. B., 1928, Some Pennsylvanian ostracodes from the Henrietta formation of eastern Missouri. Part II: Jour. Paleontology, v. 2, p. 318–337, pls. 43,44.

KOSANKE, R. M., 1950, Pennsylvanian spores of Illinois and their use in correlation: Illinois Geol. Survey, Bull. 74, 128 p., 17 pls.

MCCOY, FREDERICK, 1844, A synopsis of the characters of the Carboniferous limestone fossils of Ireland: Dublin, University Press, 207 p., 29 pls.

MCLAUGHLIN, K. P., 1952, Microfauna of the Pennsylvanian Glen Eyrie formation. Colorado: Jour. Paleontology, v. 26, p. 613–621, pls. 82,83.

MÜLLER, G. W., 1894, Fauna und Flora des Golfes von Neapel. Mon. 21: 404 p., 40 pls.

PAYNE, K. A., 1937, Pennsylvanian Ostracoda from Sullivan County, Indiana: Jour. Paleontology, v. 11, p. 276–288, pls. 38–40.

PRZIBRAM, HANS, 1931, Connecting laws of animal morphology: London, London Univ. Press, 62 p.

SHAVER, R. H., 1953, Ontogeny and sexual dimorphism in *Cytherella bullata:* Jour. Paleontology, v. 27, p. 471–480.

——, 1958, A study of *Pseudobythocypris pediformis*, a new name for an old ostracod: Am. Midland Naturalist, v. 59, p. 120–137.

SYLVESTER-BRADLEY, P. C., 1951, The subspecies in paleontology: Geol. Mag., v. 88, p. 88–102.

——, 1958, The description of fossil populations: Jour. Paleontology, v. 32, p. 214–235.

TASCH, PAUL, 1955, The triangular graph in population analysis—uses and limitations: Jour. Paleontology, v. 29, p. 171–177.

THOMPSON, M. L., SHAVER, R. H. & RIGGS, E. A., 1959, Early Pennsylvanian fusulinids and ostracods of the Illinois Basin: Jour. Paleontology, v. 33, p. 770–792.

WADDELL, COURTNEY, 1954, Geology and coal deposits of the Shelburn quadrangle, Sullivan County, Indiana: U. S. Geol. Survey, Coal Inv. Map C17.

WANLESS, H. R. & SIEVER, RAYMOND, 1956, Classification of the Pennsylvanian rocks of Illinois as of 1956; Correlation chart: Illinois Geol. Survey, Circ. 217, 14 p., 1 pl.

WARTHIN, A. S., JR., 1930, Micropaleontology of the Wetumka, Wewoka, and Holdenville formations: Oklahoma Geol. Survey, Bull. 53, 95 p., 7 pls.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 671–681, 7 TEXT-FIGS., JULY, 1960

THE GEOLOGIC SIGNIFICANCE OF COILING RATIOS IN THE FORAMINIFER *GLOBIGERINA PACHYDERMA* (EHRENBERG)

ORVILLE L. BANDY
University of Southern California, Los Angeles

ABSTRACT—Studies of Recent populations of the planktonic foraminifer, *Globigerina pachyderma* (Ehrenberg), show that more than 98 percent of Arctic and Antarctic specimens coil in a counter-clockwise direction (sinistral), whereas populations in temperate and tropical regions are mostly 98 percent clockwise (dextral) in manner of coiling. Basin cores off southern California reveal that modern dextral forms have persisted for about 11,000 years and were preceded by sinistral populations in the late Pleistocene, as determined by radiocarbon dating. Computations of sedimentation rates indicate that Pleistocene sediments were deposited from 25 to 500 percent faster than those in the Recent.

Investigation of populations in Pliocene and Pleistocene strata of southern California show consistent sinistrality in the Pleistocene and in the middle part of the Pliocene. Assemblages from the upper and lower Pliocene are dominantly dextral. Thus, an additional stratigraphic tool is provided in improving the accuracy of Late Cenozoic correlations of southern California.

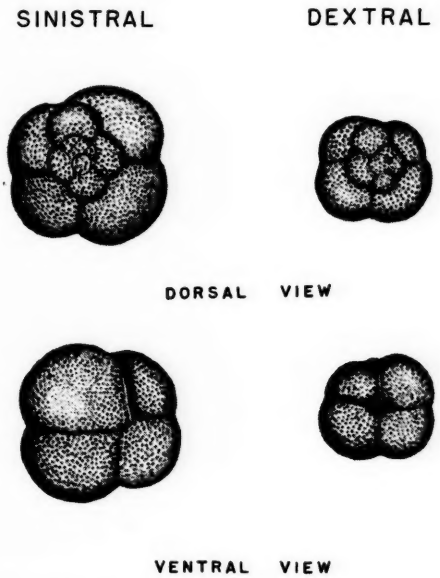
INTRODUCTION

FAUNAL trends were studied in the planktonic foraminiferal populations from cores of deep basins off southern California in an effort to develop criteria for the recognition of the Pleistocene-Recent boundary there. It was found that coiling ratios of *Globigerina pachyderma* (Ehrenberg) provided a possible geologic tool for the identification of this boundary. This discovery prompted an examination of the coiling patterns of this species in sediments of modern oceans and in later Cenozoic strata of southern California.

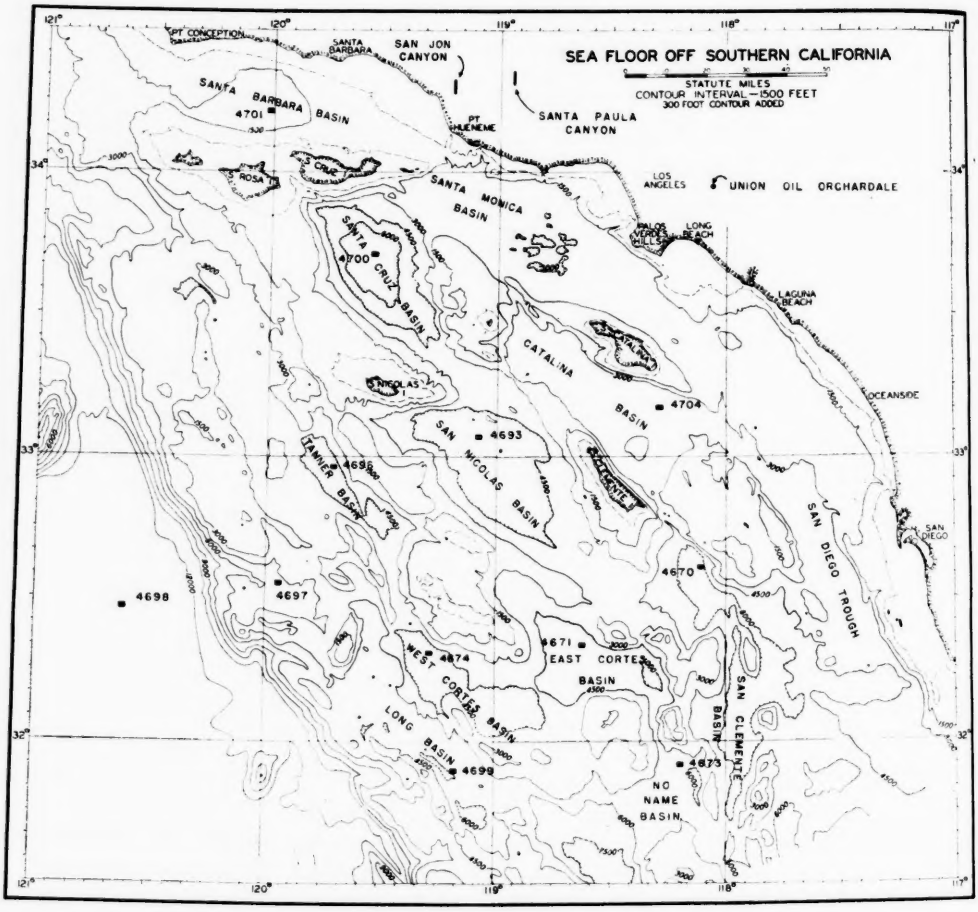
Coiling ratios were determined in the same manner as that used in the study of gastropods. As observed from the dorsal side of spirally coiled Foraminifera, dextrality or right coiling refers to those specimens that are coiled in a clockwise direction, and sinistrality or left coiling to those that have a counterclockwise coil (Text-fig. 1).

The original work of Bolli (1950, 1951) established the value of coiling ratios of planktonic Foraminifera as a stratigraphic tool. Bolli discovered that species coil about equally sinistrally and dextrally when they first appear in the geologic column, and they later exhibit preferential coiling patterns in the remainder of their biochrons. Since then, Ericson, Wollin & Wollin (1954) and Ericson & Wollin (1956a,b) have correlated Quaternary strata from deep-sea cores of the Atlantic Ocean by using coiling ratios of *Globorotalia truncatulinoides* (d'Orbigny). More recently, Nagappa (1957) applied coiling ratios to the solution of stratigraphic problems in Asia.

Cores were used from each of 10 basins, from the continental slope, and from the deep sea off southern California (Text-fig. 2). All were collected with the University of



TEXT-FIG. 1—Dextral (right coiling) and sinistral (left coiling) specimens of *Globigerina pachyderma* (Ehrenberg).



TEXT-FIG. 2—Positions of cores and sections for which analyses were made, showing relation to basins off southern California.

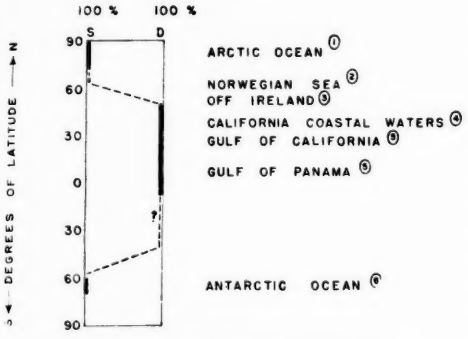
Southern California Marine Laboratory vessel, *Velero IV*, by the staff of the Allan Hancock Foundation, University of Southern California. Samples of the later Cenozoic strata of the Los Angeles and Ventura basins were made available by J. M. Hamill of The Texas Company and D. B. Braislin of the Union Oil Company of California. Samples of the Pleistocene sections of southern California were collected from the Palos Verdes Hills and adjacent areas.

Grateful acknowledgment is made of the suggestions and aid of K. O. Emery of the University of Southern California who made available sediment data from his study of basin sediments of the continental borderland of California, a project sponsored by the National Science Foundation (Emery, 1960). A part of that project required the radiocarbon dating of sediments at the bottoms of cores taken from the basins. The dating was done by R. A. Rafter, Department of Scientific and Industrial Research, Lower Hutt, New Zealand. These are the absolute dates that are referred to in the present study. Bradford Jones of the Union Oil Company offered helpful advice about the Ventura basin samples which were made available to the author for statistical analyses.

This is an Allan Hancock Foundation Contribution.

MODERN COILING HABITS OF *GLOBIGERINA PACHYDERMA*

Green (1958) discovered that more than 98 percent of the populations of *Globigerina pachyderma* were sinistral in the Arctic Ocean. Comparison of Green's samples and other samples of Recent sediments from many parts of the world indicate that both Arctic and Antarctic Oceans have dominant sinistrally coiled populations (Text-fig. 3); conversely, dextral populations occur in tropical and temperate regions of the world where they exhibit a non-continuous



TEXT-FIG. 3—Coiling ratios of *Globigerina pachyderma* plotted against latitude.

distribution pattern. In the anomalous tropical and temperate areas, they appear to occur principally where there is upwelling of colder waters, as illustrated by the abundance of *G. pachyderma* in most of the basins off California, along the coast of Central America, and in the Gulf of California. Upwelling and periodic plankton blooms are well known in these areas (Sverdrup, Johnson & Fleming, 1942; Roden, 1958). Bottom sediments from the Asiatic coast and the mid-Pacific either lacked specimens or had only a few dextral individuals.

Transition from the southern dextral to northern sinistral populations in the North Atlantic occurs between Ireland and Iceland, and this also agrees with a major subdivision of the water masses there. Sampling density in the Pacific Ocean is not adequate to demonstrate detailed patterns of occurrence and coiling characteristics; however, it is sufficient to justify dominant dextrality in much of the eastern Pacific in tropical and temperate waters. It may be assumed that sinistral northern populations invade the northern temperate regions along the paths of cold currents from the north, and from the Antarctic region northward into the southern part of the temperate region there.

Probable temperature control or modification of coiling provinces of planktonic species is seen in the study of *Globorotalia truncatulinoides* by Ericson, Wollin & Wollin (1954, fig. 2). All of the tropical populations of this species are dextral in the Atlantic Ocean, whereas the temperate regions have mostly sinistral populations, with but two limited dextral provinces. One of these temperate dextral provinces occurs along the Atlantic coast of North America, and the second is in the northeastern Atlantic off western Europe. A probable explanation of these exceptions is that the Gulf Stream carries dextral populations along with it northward into the temperate region, across the Atlantic in the very narrow belt of the North Atlantic current at about the 40 degree parallel, and into a larger province of dextrality off western Europe where the North Atlantic current breaks up into large eddies (Sverdrup, Johnson & Fleming, 1942, chart 7). The investigation by Ericson, *et al.*, shows essentially a blank area along the narrow path of the North Atlantic current so that data are lacking to substantiate the connection between these two northern dextral provinces.

It would seem that temperature has some control upon the coiling habit of various Foraminifera, perhaps by affecting the chemical processes in the genes, favoring mutations for the production of dextral dominance in some species (*Globigerina pachyderma*) in warm waters, and the reverse in cold waters. Other planktonic species are found to be dominantly sinistral in tropical waters (*Globorotalia tumida*), showing that different species may respond in opposite ways.

CORRELATIONS IN LATER CENOZOIC STRATA OF SOUTHERN CALIFORNIA

The Recent-Pleistocene Boundary.—Plots were made of the coiling ratios, abundances, and stratigraphic occurrences of all plank-

tonic Foraminifera in samples of 12 cores from the continental borderland of southern California. Benthonic species were omitted because of the tremendous benthic facies variation from basin to basin (Crouch, 1952). *Globigerina pachyderma* (Ehrenberg) proved to be of greatest value because it is abundant in most of the core samples, and it shows consistency in dextrality in the upper portions of the cores and sinistrality in the lower portions of many cores (Text-fig. 4). The basins in Text-figure 4 are arranged in order of increasing sill depth from left to right, with the cores for the continental slope and the deep sea on the right. Radiocarbon dates are given for those core segments that have been dated. The specimens of *G. pachyderma* in every core dated less than 11,000 years old show mostly pronounced dextrality, whereas those which are older than this exhibit a pronounced shift to sinistrality. There was a temporary shift to dextrality between 15,000 and 16,000 years ago evidenced in the Santa Catalina (4704), San Nicolas (4693), and No Name (4673) basins. Less perceptible evidence of shifts may be seen in the Tanner (4696) and West Cortes (4674) basins. The 11,000 year shift from sinistral to dextral dominance is assumed to be the approximate boundary between the Pleistocene and Recent, which is in agreement with the data of Ericson & Wollin (1956b) for the Caribbean and equatorial Atlantic regions.

Complex topographic features of the southern California borderland suggest that the precise time of shifting from sinistral to dextral populations might not have been contemporaneous in the entire region. The change could have spanned several hundred years, perhaps a thousand years or so, occurring first in the outer basins and later in the inner basins.

Assuming that the last prominent change from sinistral to dextral populations of *Globigerina pachyderma* represents an age of about 11,000 years BP (before the present), it is interesting to assess the changes in sedimentation rates before and after this point as a measure of Pleistocene versus Recent rates. Table 1 presents sedimentation rates in numbers of years per centimeter without correction for compaction or turbidity current deposits, and number of years per gram of dry sediment corrected for both compaction and turbidity current deposits. Years per gram of dry sediment were extrapolated from data by K. O. Emery (1960). Using either set of data, the general trend for the Recent interval is about the same with a

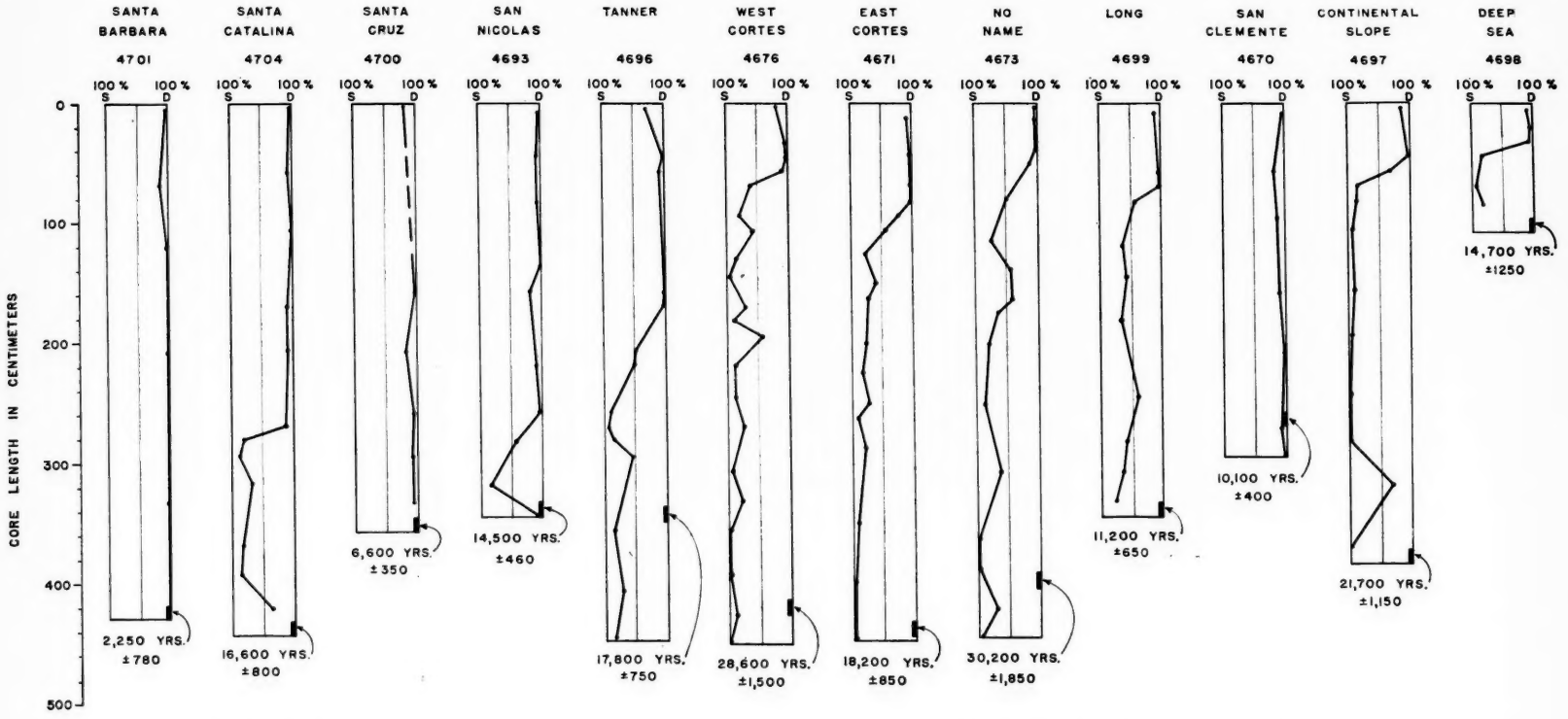
TABLE 1.—SEDIMENTATION RATES IN YEARS PER CENTIMETER AND YEARS PER GRAM*

AHF No.	Basin	Depth in Meters		Sedimentation Rates in Years			
		Bottom	Sill	Recent		Pleistocene	
				CM	G	CM	G
4701	Santa Barbara	627	475	5	12	—	—
4704	Santa Catalina	1,357	982	39	80	33	59
4700	Santa Cruz	1,966	1,085	30	12	—	—
4693	San Nicolas	1,833	1,106	38	73	?	116
4696	Tanner	1,551	1,165	49	116	30	91
4674	West Cortes	1,796	1,362	173	297	46	67
4671	East Cortes	1,979	1,415	102	175	22	34
4673	No Name	1,915	1,553	144	268	52	87
4699	Long	1,938	1,697	—	59[1]	—	8
				31	262[2]	—	2
4670	San Clemente	2,107	1,816	33	46	—	—
4697	Continental Slope	1,674	—	180	292	33	45
4698	Deep Sea	3,752	—	289	582	54	425

* Note that the figures for years per centimeter are not corrected for compaction or turbidity current deposits. The figures for years per gram of dry sediment are extrapolated from data by Emery (1960) and have been corrected for both compaction and turbidity current deposits.

[1] Values assuming that most of the core is less than 11,000 years old.

[2] Values assuming that only the upper 76 cm. of the core are less than 11,000 years old. See core data in text-figure 4.

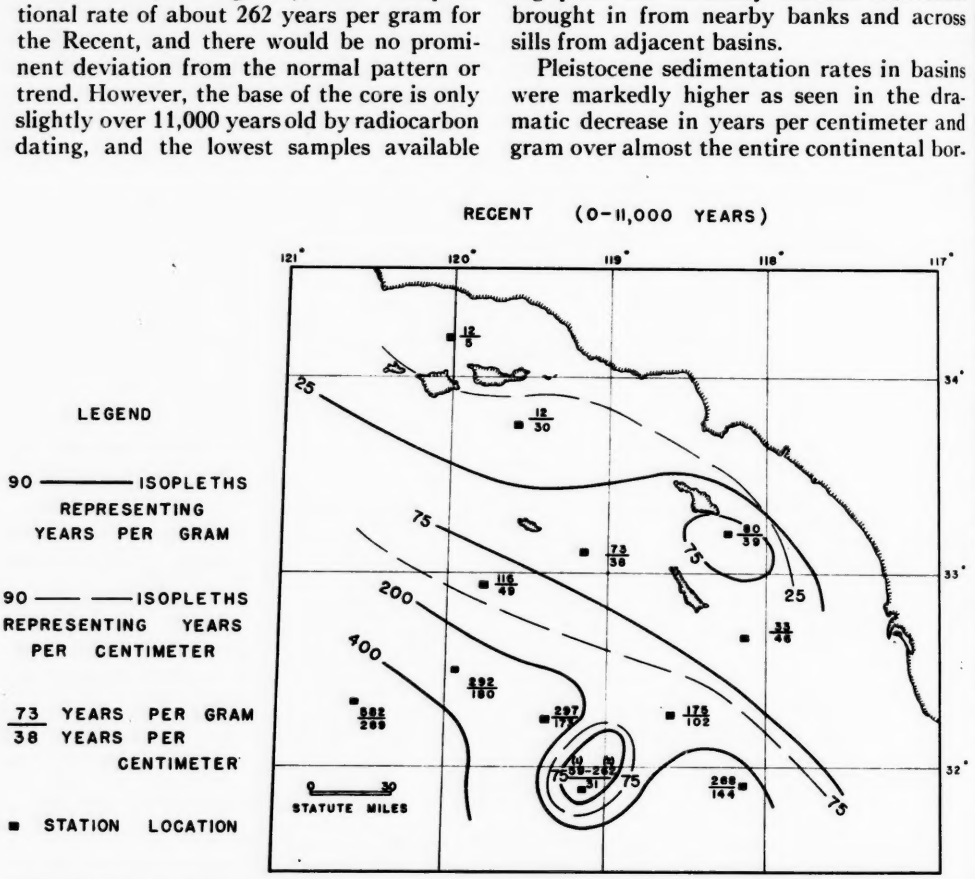


TEXT-FIG. 4—Coiling ratios of *Globigerina pachyderma* in cores from basins, the continental slope, and the deep sea off southern California, with radiocarbon dates. See Text-figure 1 for locations.

Two additional carbon-14 ages became available while the paper was in press. Sample 4671 (East Cortes Basin), 89–102 cm., age 12,400 years, which is from the interval in which coiling ratios change from left to right-coiling. Sample 4704 (Santa Catalina Basin), 280–292 cm., age 13,800 years, which is just below the interval in which coiling ratios change from left to right coiling. Both samples were selected as a check on the age of 11,000 years as the point at which the coiling ratios changed. It now would appear that an age of about 12,000 years ago is a better figure for the change.

rate of less than 30 years per centimeter or gram near shore, and a progressive decline offshore to more than 400 years per gram or 200 years per centimeter along the outer continental slope and in the deep sea (Text-fig. 5A). Long Basin (4699) provides an exception to the general trend. In Text-figure 4 it may be seen that the coiling preference is not well developed excepting in the upper 76 cm. where the trend is dominantly toward dextrality. The bottom of the core is dated as 11,300 years, thus most of the core was deposited in a period of a few hundred years if it is assumed that dextral dominance at 76 cm. is the 11,000 year point. This assumption would result in alternative 2 (Text-fig. 5A), with a depositional rate of about 262 years per gram for the Recent, and there would be no prominent deviation from the normal pattern or trend. However, the base of the core is only slightly over 11,000 years old by radiocarbon dating, and the lowest samples available show a distinct trend away from sinistrality to about equal numbers of sinistral and dextral specimens for the major length of the core. It is possible that reworking of middle Pliocene and Pleistocene sinistral specimens has camouflaged the Recent dextral populations in much of the core. The presence of middle Pliocene benthic species of the *Bulimina subacuminata* Zone corroborates this possibility. Assuming that the radiocarbon dating is correct and that most of the core is less than 11,000 years old (alternative 1, Text-fig. 5A), the depositional rate in this basin is comparatively rapid, an anomaly that is not easily explained with available data. Perhaps this basin is the final resting place for turbidity current sediments brought in from nearby banks and across sills from adjacent basins.

Pleistocene sedimentation rates in basins were markedly higher as seen in the dramatic decrease in years per centimeter and gram over almost the entire continental bor-

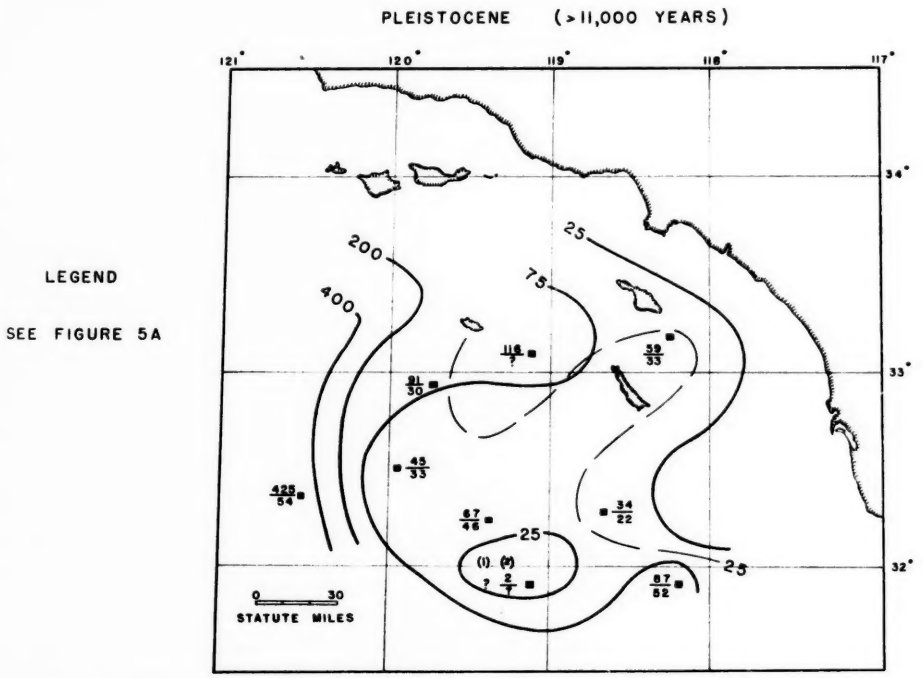


TEXT-FIG. 5A—Sedimentation rates for the Recent (0–11,000 years) in years per gram of dry sediment and years per centimeter. (1) Calculation for core 4699 assuming 11,000 years is represented at a core depth of 300 cm. (2) Calculation for the same core assuming 11,000 years is represented at a core depth of 76 cm.

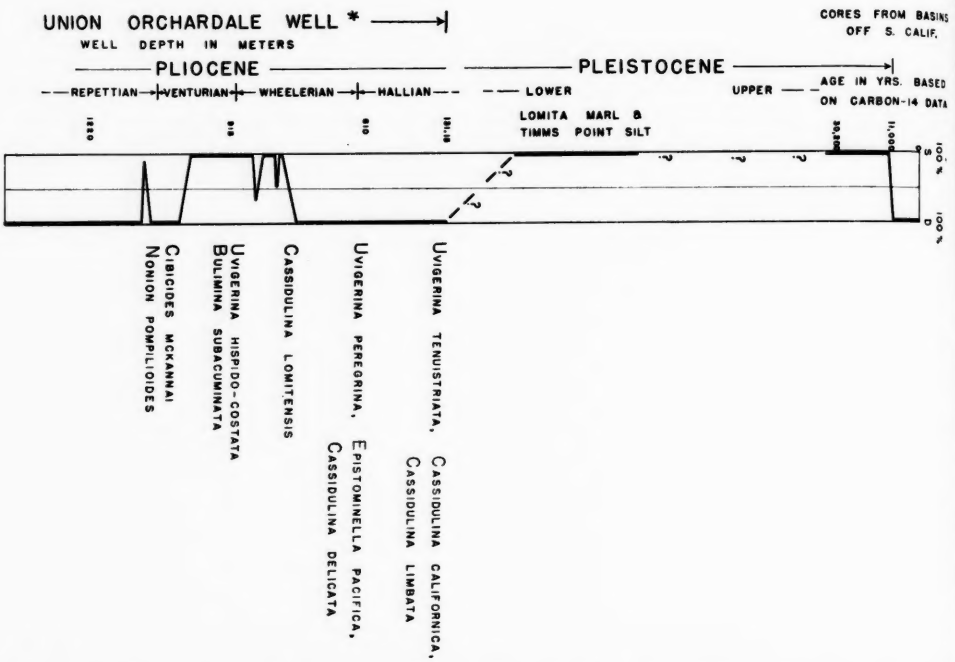
derland (Text-fig. 5B). Values range from a relatively rapid 34 years per gram in East Cortes Basin to a slow rate of 425 years per gram in the deep sea. The range of values is much less for years per centimeter, with the most rapid rate of 22 years per centimeter in East Cortes, and a slow rate of 54 years per centimeter in the deep sea. Isopleths for sedimentation rates, whether years per gram or centimeter, lack the parallelism to the coastal region that is true of the Recent interval. Generally, there seems to have been a re-entrant of slower deposition south of the channel islands, and a large lobe of more rapid deposition to the south.

Late Cenozoic Coiling Ratios in the Los Angeles Basin.—It was necessary to construct a composite analysis of the coiling ratios of *Globigerina pachyderma* for the later Cenozoic strata of the Los Angeles Basin (Text-fig. 6), since no available single surface or well section was complete. The end of the Pleistocene is represented by the core analyses of the offshore basins, with the boundary defined by Recent dextrality and Pleistocene sinistrality. Lower Pleistocene sections, sampled in the Palos Verdes Hills, include the Lomita marl and Timms Point silt. Exact localities sampled are those presented by Woodring, Bramlette & Kew (1946). Their localities 34 and 35 were sampled for the Timms Point silt, and their locality 42 (a–i) is the section used for the Lomita marl. All Pleistocene samples contained dominantly sinistral populations.

Pliocene ratios were determined for the Union Orchardale Well near Santa Fe Springs, California, representing the central part of the Los Angeles Basin. Using Natland's designations for the Pliocene stages (1953) of the southern California region, the upper Pliocene Hallian and the upper part of the Wheelerian have dominant dextral populations of *Globigerina pachyderma* indicating that this section is pre-Pleistocene. Midway through the Wheelerian, there is a significant shift to sinistrality and, with the exception of a few brief reversals to dextrality, this trend continues down to a point just above the top of the Repettian or lower



TEXT-FIG. *5B*—Sedimentation rates for the Pleistocene core segments (pre-11,000 years) in years per gram of dry sediment and years per centimeter.



TEXT-FIG. 6—Coiling ratios of *Globigerina pachyderma* in the later Cenozoic strata of the Los Angeles Basin from a well located in sec. 10, T. 3 S., R. 11 W., approximately 4.8 km. east of Santa Fe Springs, California.

Pliocene. The lower Pliocene is almost entirely composed of dextral populations with only one brief reversal to sinistrality just below the top of the *Nonion pompilioides* Zone.

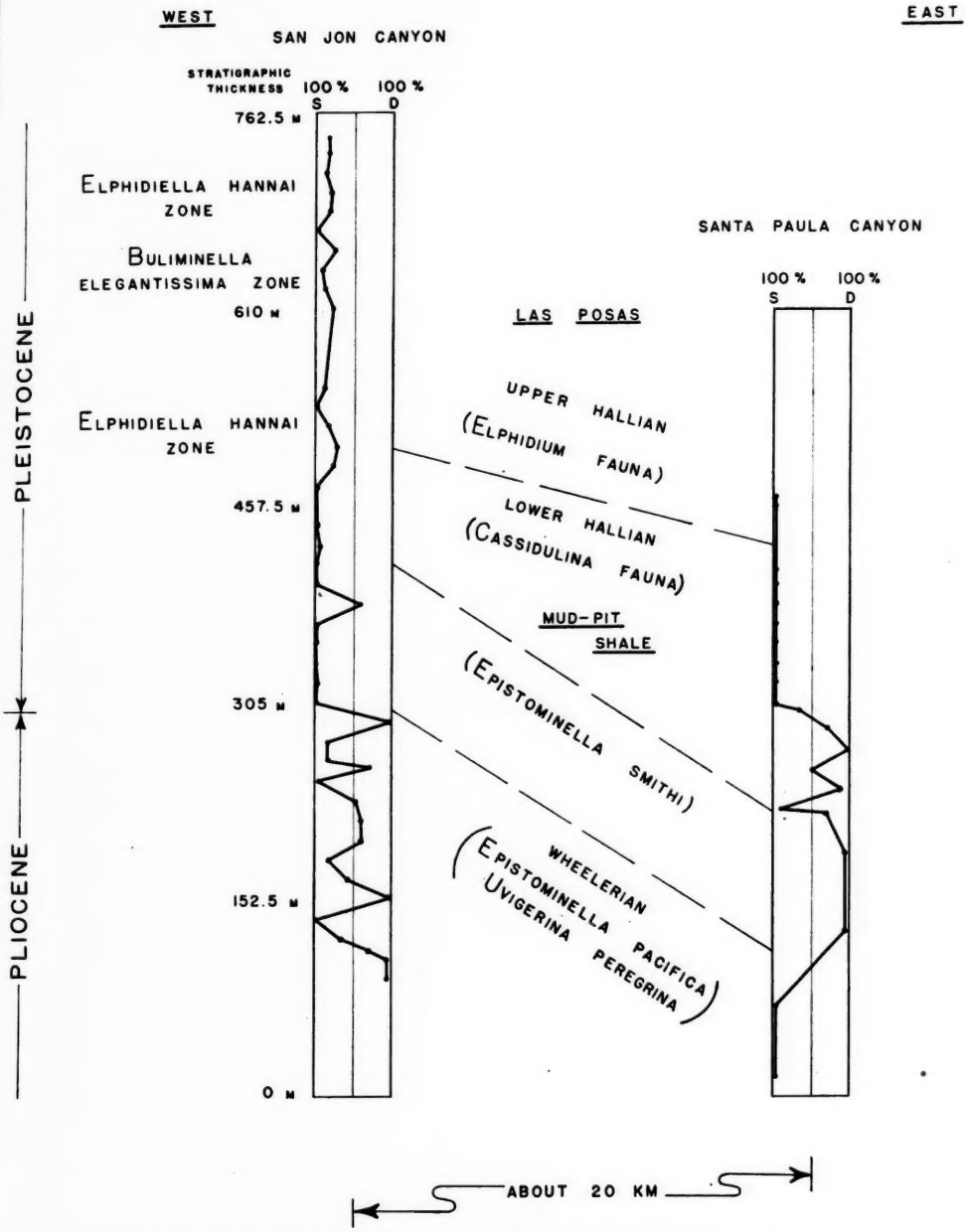
Thus, dextral populations characterize the Recent, uppermost Pliocene, and lower Pliocene. Sinistral populations are dominant in Pleistocene strata and in the middle portion of the Pliocene section of the Los Angeles Basin. Coiling criteria are useful in establishing the proper correlation of questionable upper Pliocene or lower Pleistocene strata.

Definition of the Pliocene-Pleistocene Boundary in the Ventura Basin.—Natland's zonation of the Pliocene and Pleistocene of southern California includes an upper Pliocene stage, the Wheelerian, and a lower Pleistocene stage, the Hallian, as based upon his study of benthic faunas (1953). The Wheelerian is defined by the presence of *Epistominella pacifica* and *Uvigerina peregrina*, which suggest deeper water conditions of more than 300 meters. Lower Hallian assemblages are mostly *Cassidulina* faunas, representing water depths of between 50 and 300 meters. Upper Hallian assemblages are dominantly *Elphidium-Streblus* faunas, which suggest inner shelf conditions or water depths of less than 50 meters. Thus, pronounced shoaling occurred in the late Pliocene and early Pleistocene of the Ventura Basin, largely due to more rapid deposition than subsidence (Bandy, 1953, Pt. II).

Holman has illustrated recently how the stages of the late Cenozoic of the Ventura Basin do not reflect true time units (1958). For example, Hallian faunas of the eastern part of the basin are upper Pliocene; those of the central part of the basin are largely lower Pleistocene. However, he did not offer criteria for determining the actual time boundary as opposed to the facies boundary.

Assuming that variations in preferential coiling directions were regional in scope and essentially simultaneous in time, plots were made of the coiling directions of *Globigerina pachyderma* across the Pleistocene-Pliocene

boundary in two sections of the Ventura Basin. One section is in San Jon Canyon, and the other is located about 20 km. to the east in Santa Paula Canyon (Text-figs. 2, 7). San Jon Canyon is a north-south canyon about 1½ km. west of Hall Canyon in the Ventura Avenue oil field; Santa Paula Canyon is in the eastern part of the Ventura



TEXT-FIG. 7—Definition of the Pliocene-Pleistocene boundary in the Ventura Basin, based upon coiling ratios of *Globigerina pachyderma*.

Basin. Placement of the Pliocene-Pleistocene boundary at the point at which upper Pliocene dextral populations give way to Pleistocene sinistral populations more or less coincides with the Wheelerian-Hallian contact as based upon benthic faunal groups in the San Jon Canyon section. About 20 km. to the east, toward the edge of the basin, the top of the Wheelerian is about 180 meters below the top of the largely dextral populations of the upper Pliocene. Thus, the transition through the successive stages of Natland occurred progressively earlier toward the eastern edge of the basin as determined by the dextral-sinistral boundary of the planktonic foraminifer, *G. pachyderma*.

Theoretically, the implied time-transgressive nature of the benthonic facies of the late Pliocene and early Pleistocene should result in a marked contrast between the Pleistocene sequence in the western part of the basin as compared with that in the eastern marginal area. Shoal faunas of the western section are entirely Pleistocene with large distinctly colder water *Elphidiella* faunas. Toward the east, where shoaling occurred much earlier in late Pliocene time, only shoal warm water *Elphidium* faunas occur at first, giving way later to the cold water faunas. This relationship is apparent in comparing the San Jon and Santa Paula Canyon sections (Text-fig. 7).

CONCLUSIONS

1. Precise chronology in stratigraphic correlation is approximated by use of planktonic foraminiferal trends. Thus, it is possible to establish true stages of chronology for the Late Cenozoic of southern California, as opposed to apparent stages based upon benthic faunas and ecologic involvment.

2. A study of coiling ratios of *Globigerina pachyderma* suggests tentative zonation of the later Cenozoic of southern California as follows: lower Pliocene, right coiling; middle Pliocene, mostly left coiling; uppermost Pliocene, mostly right coiling; Pleistocene, left coiling; Recent, right coiling. The Pliocene zones are generally correlative only with the stages of Natland.

3. Apparent temperature control of coiling ratios in some planktonic Foraminifera suggests that the biochemistry of the gene is affected by temperature. Low temperatures favor mutations toward sinistral dominance in some species; high temperatures appear to favor mutations toward dextral dominance. Perhaps there is a genetic linkage between coiling traits and the ability to cope with different temperatures. Experimental laboratory tests are needed for the solution of this problem.

4. Planktonic organisms have been considered to be among the better types of index fossils generally, because of their more rapid dissemination over vast areas by currents. If subtle characteristics such as coiling direction can be so significant as a chronologic tool, it may be assumed that there are undoubtedly other useful traits as yet undiscovered. One of these could be variation in trace element content, another could be the amount of variation in surface structure, and still another could be found in the size ranges of the same species in different horizons.

ADDENDUM

D. B. Ericson is currently studying the coiling direction of *Globigerina pachyderma* in the North Atlantic. Since this paper was completed, he has published a short article on this work (1959).

REFERENCES

BANDY, O. L., 1953, Ecology and paleoecology of some California Foraminifera, Parts I, II: Jour. Paleontology, v. 27, p. 161–182, 200–203.

BOLLI, HANS, 1950, The direction of coiling in the evolution of some Globorotaliidae: Contrib. Cushman Found. Foram. Res., v. 1, p. 82–89.

——, 1951, Notes on the direction of coiling of rotalid Foraminifera: Contrib. Cushman Found. Foram. Res., v. 2, p. 139–143.

CROUCH, R. W., 1952, Significance of temperature on Foraminifera from deep basins off southern California coast: Am. Assoc. Petroleum Geologists, Bull., v. 36, p. 807–843.

EMERY, K. O., 1960, The sea off southern California, a modern habitat of petroleum: John Wiley and Sons, Inc., New York, 366 p.

ERICSON, D. B., 1959, Coiling direction of *Globigerina pachyderma* as a climatic index: Science, July 24, v. 130, no. 3369, p. 219–220.

ERICSON, D. B., WOLLIN, G. & WOLLIN, J., 1954, Coiling direction of *Globorotalia truncatulinoides* in deep-sea cores: Deep-Sea Res., v. 2, p. 152–158.

ERICSON, D. B. & WOLLIN, G., 1956a, Correla-

tion of six cores from the equatorial Atlantic and the Caribbean: Deep-Sea Res., v. 3, p. 104–125.

——, 1956b, Micropaleontological and isotopic determinations of Pleistocene climates: Micropaleontology, v. 2, p. 257–270.

GREEN, K. E., 1958, Ecology of some Arctic Foraminifera: Unpub. Master's thesis, Univ. Southern California.

HOLMAN, W. H., 1958, Correlation of producing zones of Ventura Basin oil fields: Am. Assoc. Petroleum Geologists, Pacific Section, Guide to Geology and Oil Fields of Los Angeles and Ventura Regions.

NAGAPPA, Y., 1957, Direction of coiling in *Globorotalia* as an aid in correlation: Micropaleontology, v. 3, p. 393–398.

NATLAND, M. L., 1953, Pliocene and Pleistocene stages in southern California: Am. Assoc. Petroleum Geologists, Pacific Section, Pacific Petroleum Geologists, v. 7, no. 2, p. 2.

ORR, W. L., EMERY, K. O. & GRADY, J. R., 1958, Preservation of chlorophyll derivatives in sediments off southern California: Am. Assoc. Petroleum Geologists, Bull., v. 42, p. 925–962.

RODEN, G. I., 1958, Oceanographic and meteorological aspects of the Gulf of California: Pacific Science, v. 12, p. 21–45.

SVERDRUP, H. U., JOHNSON, M. W. & FLEMING, R. H., 1942, The oceans: Prentice-Hall, 1087 p.

WOODRING, W. P., BRAMLETTE, M. N. & KEW, W. S. W., 1946, Geology and paleontology of Palos Verdes Hills, California: U. S. Geol. Survey, Prof. Paper 207.

APPENDIX I

ALLAN HANCOCK FOUNDATION CORE LOCATIONS AND WATER DEPTHS

AHF No. and Basin or Area	Location		Water Depth in Meters
	Lat. N.	Long. W.	
Santa Barbara Basin—4701	34°14.3′	120°02.1′	591
Santa Catalina Basin—4704	33°10.0′	118°17.3′	1,134
Santa Cruz Basin—4700	33°42.7′	119°33.0′	1,929
San Nicolas Basin—4693	33°04.0′	119°05.4′	1,774
Tanner Basin—4696	32°57.4′	119°44.5′	1,510
West Cortes Basin—4674	32°16.5′	119°19.5′	1,595
East Cortes Basin—4671	32°19.0′	118°38.0′	1,664
No Name Basin—4673	31°54.0′	118°11.0′	1,780
Long Basin—4699	31°53.5′	119°11.0′	1,769
San Clemente Basin—4670	32°37.7′	118°07.5′	2,050
Continental Slope—4697	32°33.3′	119°57.4′	1,667
Deep Sea—4698	32°28′	120°36′	3,758

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 682–694, PLS. 83–84, 2 TEXT-FIGS., JULY, 1960

TRIASSIC AMMONOIDS FROM THAILAND

BERNHARD KUMMEL
Harvard University, Cambridge, Massachusetts

ABSTRACT—The first Triassic ammonoids to be recorded from Thailand demonstrate the presence of Anisian and Karnian formations. The Anisian is represented by species of *Balatonites, Ptychites, Tropigymnites, Beyrichites,* and *Sturia;* the Karnian is represented by species of *Joannites, Cladiscites, Trachyceras* (*Paratrachyceras*), and *Lobites.* The occurrence and relationships of Triassic marine formations in southeast Asia are briefly reviewed.

FOUR specimens of ammonites were submitted to me in 1953 by MacKenzie Gordon on behalf of the Foreign Branch of the U. S. Geological Survey. These specimens were originally thought to be of Permian age on the basis of field investigations but on close examination of these specimens they turned out to be a species of *Joannites* most comparable to *Joannites klipsteini* and probably of Upper Triassic (Karnian) age. The receipt of this information prompted Dr. Vija Sethaput, the then Chief, Geological Survey Division, Royal Department of Mines, Bangkok, Thailand, to arrange for further collections to be made in the same area where the original specimens were obtained. This survey was performed by Kaset Pitakpaivan who obtained a number of additional specimens plus much needed information on the strata containing the fossils. Pitakpaivan's study was published as the first report of the Royal Department of Mines in 1955.

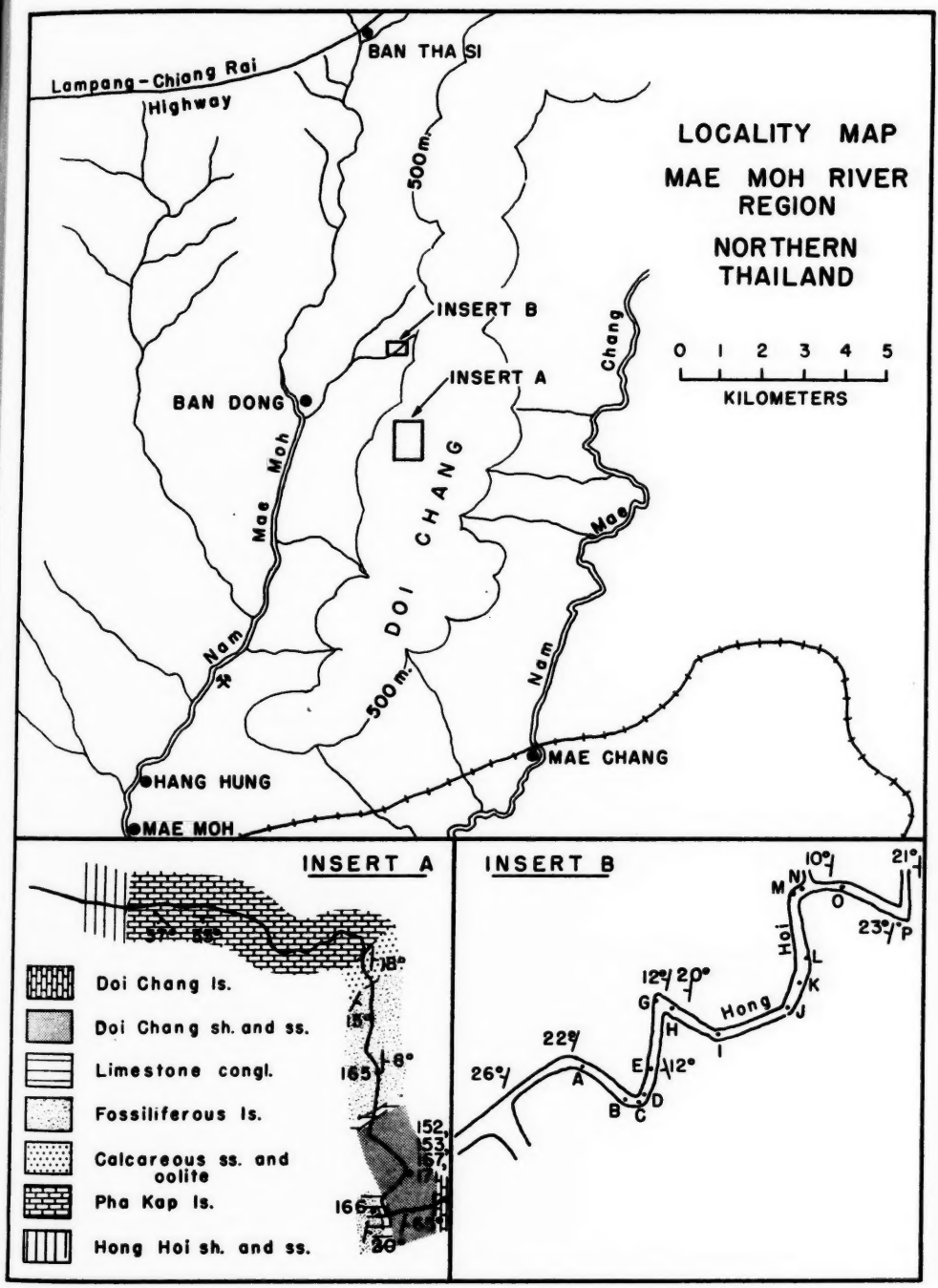
The fossils come from localities in the headwater regions of the Mae Moh River, northern Thailand (Text-fig. 1). Pitakpaivan (1955) differentiated seven sedimentary units which he named as follows:

		(Thickness estimated)
Top	Doi Chang limestone	50 meters
	Doi Chang shale and sandstone	100 meters
	Limestone conglomerate	10 meters
	Fossiliferous limestone	43 meters
	Calcareous sandstone and oolite	10 meters
	Pha Kap limestone	100 meters
	Hong Hoi shale and sandstone	100 meters

Fossils were obtained from the Doi Chang shale and sandstone, the Fossiliferous limestone, and the Hong Hoi shale and sandstone. The locality of each of the fossil lots are shown on Text-figure 1, and the faunal list from each lot is as follows:

Locality 151
Joannites cf. *J. klipsteini* (Mojsisovics)
Cladiscites cf. *C. beyrichi* Welter
Locality 153
Ptychites cf. *P. rectangulatus* Kraus
Locality 165
Spirigera sp.
Locality 167
Balatonites sp. indet. I
Balatonites sp. indet. II
Beyrichites sp. indet.
Trachyceras (*Paratrachyceras*) cf. *T.* (*P.*) *regoledanum* (Mojsisovics)
Ptychites cf. *P. rectangulatus* Kraus
Sturia sp. indet. II
Tropigymnites cf. *T. chandra* (Diener)
Locality 168
a. *Trachyceras* (*Paratrachyceras*) cf. *T.* (*P.*) *regoledanum* (Mojsisovics)
Joannites cf. *J. klipsteini* (Mojsisovics)
b. *Halobia* sp. indet.
c. *Lobites* cf. *L. ellipticus* (Hauer)
Holobia sp. indet.
g. *Trachyceras* (*Paratrachyceras*) cf. *T.* (*P.*) *regoledanum* (Mojsisovics)
h. *T.* (*Paratrachyceras*) cf. *T.* (*P.*) *regoledanum* (Mojsisovics)
j. *Balatonites* sp. indet. II
k. *Balatonites* sp. indet. II
n. *Sturia* sp. indet. I
Locality 171
Joannites cf. *J. klipsteini* (Mojsisovics)

Pitakpaivan (1955) records that locality 167 is in the Doi Chang shale and sandstone at Doi Chang; locality 168 is in the Hong Hoi shale and sandstone at Hong Hoi; locality 165 is in the Fossiliferous limestone at Doi Chang; and finally, that localities 171, 153, and 151 were collected prior to his investigation, and their exact location is not known except that they definitely came from either Hong Hoi or Doi Chang. However, maps sent me in 1954 by Dr. Sethaput clearly show that localities 151 and 171 are from Hong Hoi, and locality 153 is at Doi Chang. At the same time no data are available as to the relative stratigraphic position of localities 151 and 171 with the specimens



TEXT-FIG. 1—Sketch map of Mae Moh River region from which Triassic fossils were obtained. The insert maps show details of the two principal collecting areas. Maps based on data assembled by Kaset Pitakpaivan.

of locality 168 shown on Text-figure 1.

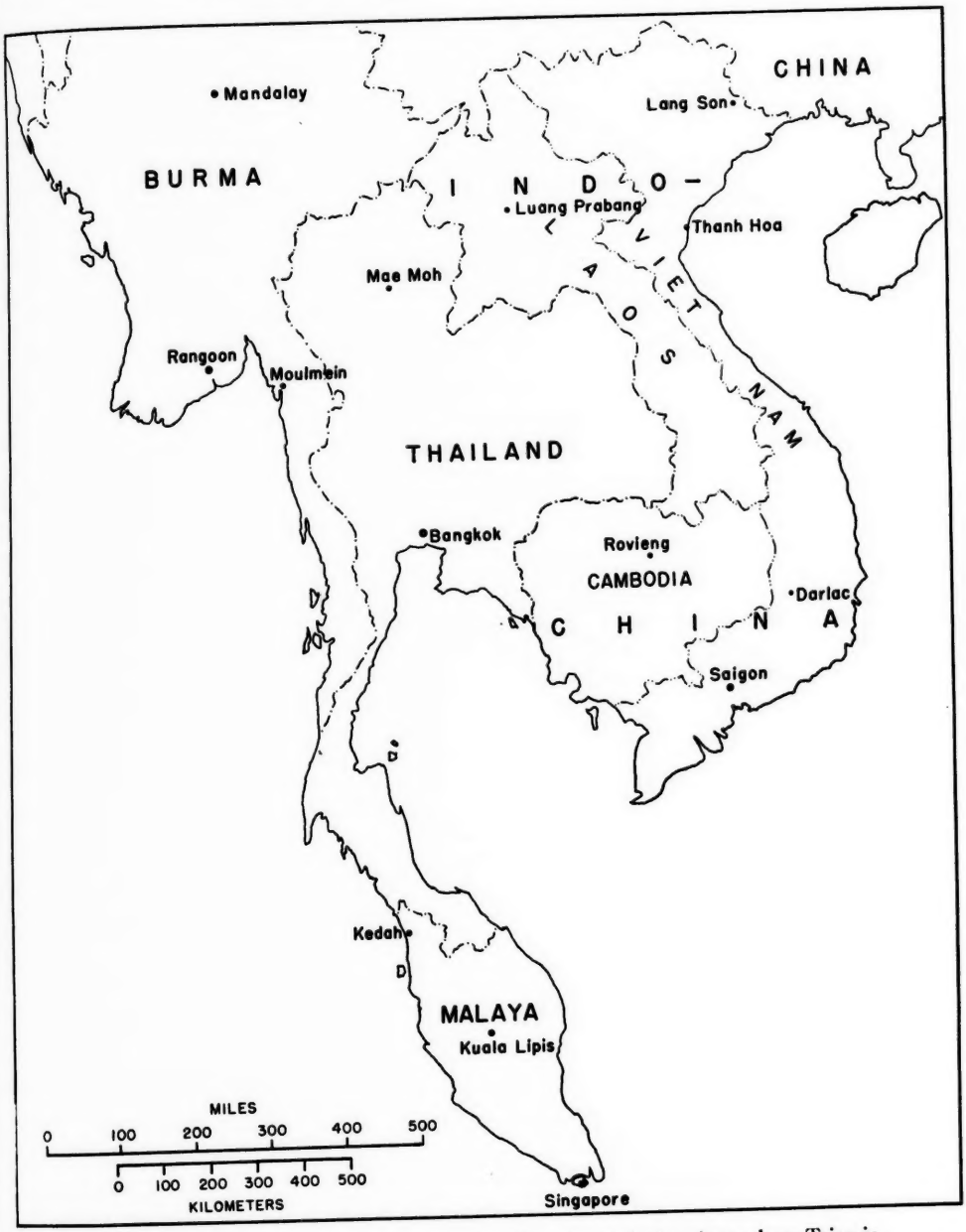
The specimens from localities 151, 171, and 168a–h suggest an Upper Triassic age (Karnian). The specimens from localities 153, 167, and 168j,k,n suggest a Middle Triassic age (Anisian). The map of the outcrop area of locality 168 (in the Hong Hoi shale and sandstone) shows a westerly dipping sequence (Text-fig. 1). The uppermost beds (localities 168a–h) are without question Upper Triassic, and the lower beds (localities 168j,k,n) contain poorly preserved, crushed specimens which appear to be correctly assigned to *Balatonites* and *Sturia*, typical Middle Triassic genera. Only one of the specimens from locality 167 (Doi Chang shale and sandstone) does not fit a Middle Triassic age assignment. This is *Trachyceras* (*Paratrachyceras*) cf. *T.* (*P.*) *regoledanum* (Mojsisovics). The identification of this specimen is open to question. Even though it is fragmentary, the specimen clearly has morphological features identical with the specimens of that species listed from localities 168g and 168h, but the preservation is quite different. The species of *T.* (*Paratrachyceras*) are known mainly from Ladinian and Karnian horizons (see Arthaber, 1914; Kutassy, 1933). Only one species, *T.* (*P.*) *rutoranum*, is recorded from the Anisian, and this is very different from the Thailand species. It seems best to disregard this specimen of *T.* (*Paratrachyceras*) from the faunal list of locality 167; in this way by relying on the remaining elements of the fauna the Middle Triassic age is readily apparent.

The fossil data suggest that there must be some sort of error in the stratigraphic sequence at Mae Moh, possibly due to faulting. The highest stratigraphic unit, the Doi Chang shale and sandstone, is on the basis of the contained fauna most probably Anisian in age; the lowest fossiliferous unit, the Hong Hoi shale, is mainly Upper Triassic (Karnian) with the lower part of the section most probably Anisian in age.

Triassic of Southeast Asia.—A number of Triassic faunas are now known from southeast Asia but these consist mainly of small faunas of pelecypods. Ammonoids are a significant part of the fauna only in Indochina, no ammonoids are known from Triassic formations of Burma, ammonoids are present in Malaya, and this report is the first record of Triassic faunas from Thailand. The Triassic faunas of southeast Asia are of particular interest since the area is at the eastern limits of Tethys and borders on the circum-Pacific geosynclinal belt. Likewise this region lies between two of the classical areas for Triassic faunas, namely the Himalayas and Timor. None of the Triassic localities and faunas known to date from southeast Asia is anywhere comparable to the abundance and diversity of the faunas known from the Himalayas and Timor. A brief review of the Triassic faunas of southeast Asia will give better perspective as to the significance and relationship of the fauna described here from Thailand (Text-fig. 2).

The first fossils collected in Malaya were Upper Triassic pelecypods from near Kuala Lipis in the province of Pahang (Scrivenor, 1926). This fauna was described by Newton (1900) who concluded they were of Rhaetic age. A somewhat similar fauna was later discovered in Singapore, which Newton (1923) likewise concluded was probably of Rhaetic age but possibly slightly older since it contained "both St. Cassian and Muschelkalk species." A number of additional collections have been made in the region of Kuala Lipis and at Singapore. Restudy of these faunas (mainly pelecypods) indicates they are most probably Karnian in age (Wier, 1925; Cox, 1936; Cox in Savage, 1950). Recently, Savage (1950) discovered an ammonoid fauna in the vicinity of Kuala Lipis. These specimens were examined by L. F. Spath, who recognized a number of Middle Triassic (Anisian) genera, including *Paraceratites*, *Sturia*, *Ptychites*, and *Acrochordiceras*. This fauna has been restudied by the author who recognized the following species: *Paraceratites trinodosus* (Mojsisovics), *Sturia sansovinii* Mojsisovics, *Acrochordiceras* sp. indet., *Ptychites* sp. indet. (Kummel, 1959).

From northern Malaya near the border with Thailand in the province of Kedah, Newton (1925) records "*Halobia*"-like pelecypods and two indeterminant ammonoids. The pelecypods appear to be most closely similar to Middle Triassic forms. Newton also concluded that the phyllopods described by Jones (1905) from the province of Perak are actually pelecypods like those from Kedah, and not crustaceans. The first



TEXT-FIG. 2—Southeast Asia showing locality of principal regions where Triassic faunas are known.

of the two specimens of ammonoids Newton indicated as *Ammonites* indet. "A" and suggested that it may be referred to a form of the Arcestidae. It seems more likely that it probably is a *Juvavites* or possibly an *Anatomites* but the specimen lacks the characteristic constrictions of these genera (Spath, 1951, p. 106, footnote). The second specimen Newton listed as *Ammonites* sp. indet. "B" and suggested a resemblance to *Bala-*

tonites. This specimen Spath (1951, p. 15) suggests may be *Hannoceras nasturtium* (Mojsisovics).

Massive limestones (the Kamawkala limestone) crop out along the Burma-Thailand boundary in the Amherst district of southern Burma that contain fossils considered to be Upper Triassic in age. The faunas so far obtained from these limestones are poorly preserved but study of the corals by Gregory (1930), the brachiopods and pelecypods by Wier (1930), miscellaneous fossils by Trauth (1930), and fossil algae by Pia (1930) uniformly indicate an Upper Triassic age. A few specimens of ammonoids were in the collections which Spath (in Gregory, 1930) considered hopelessly too poorly preserved for determination. Trauth (1930, p. 176) however, identified a *Trachyceras* sp. in the collections submitted to him.

The only other Triassic in Burma are the famous Rhaetic Napeng beds of the northern Sham states studied by LaTouche (1913).

Triassic formations crop out extensively over much of Indochina, and the literature describing the formations and fossils is large. Unfortunately, the faunas described to date are for the most part poorly preserved and thus difficult to interpret. This brief summation is based largely on the splendid synthesis by Saurin (1956) to which the reader is referred for specific bibliographic citations. Only the more important ammonite-bearing deposits will be mentioned.

Scythian formations with ammonites are known from around Lang-Son, Tonkin and also to the south of Luang-Prabang. The ammonoids from these localities appear to be approximately mid-Scythian in age. Anisian faunas, comparable with those from Thailand recorded here, are known from a number of places in Indochina. In northeastern Laos and northern Annam, such Middle Triassic species as the following are recognized: *Monophyllites suessi*, *M. confucii*, *Beyrichites* aff. *B. reutteuse*, *Ceratites* cf. *C. circumplicati*, *Ceratites* aff. *C. trinodosus*, *Ceratites* cf. *C. airavata*, *Ceratites samneuaensis*, *Cuccoceras* sp., *Balatonites* cf. *B. zitteli*, *B. gemmatus* etc. In the region of Plouk and Rovieng, eastern Cambodia Middle Triassic ammonoids as *Ceratites trinodosus*, *Beyrichites khanikofi*, and *Balatonites* cf. *B. zitteli* have been recorded.

Ladinian formations and faunas are less well known and recognized only in northern Indochina (Tonkin and northern Laos). Karnian faunas, however, are much more widespread and diverse, especially in Tonkin and northern Laos. These faunas are well represented by tropitids and other trachyostracan upper Triassic ammonoids. The Karnian is also known from southern Indochina, in Cochinchina and Cambodia. Norian formations have about the same distribution, and in several localities Norian ammonoids are associated with forms characteristic of the Napeng Beds of Burma which are considered to be of Rhaetian age by many.

EXPLANATION OF PLATE 83

FIGS. *1,2—Trachyceras* (*Paratrachyceras*) cf. *T.* (*P.*) *regoledanum* (Mojsisovics). M.C.Z. 5230, from loc. 167, Doi Chang shale and sandstone, Doi Chang, Thailand. ×1.

3—Balatonites sp. indet. I. M.C.Z. 5245, from loc. 167, Doi Chang shale and sandstone, Doi Chang, Thailand. ×1.

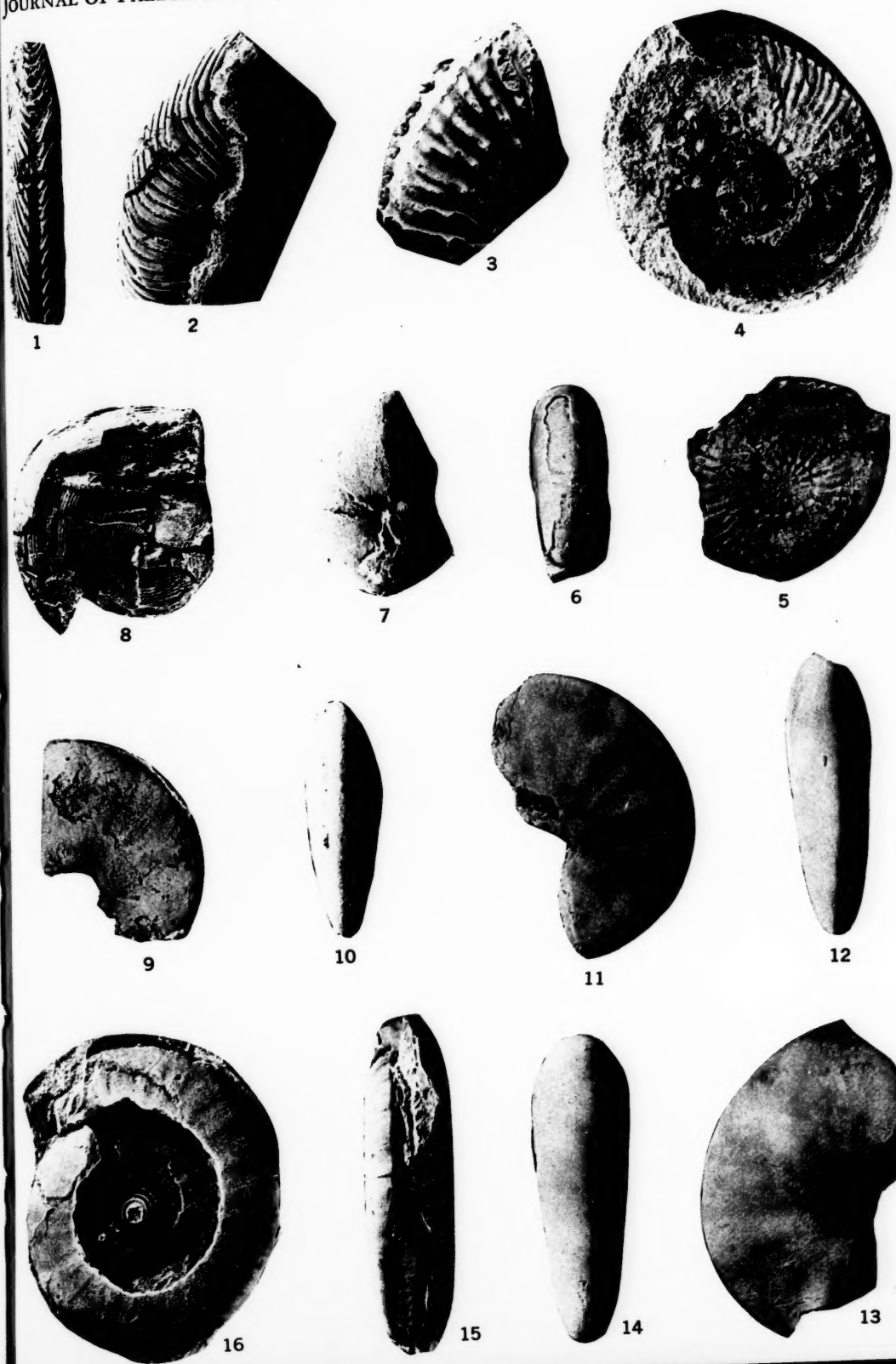
4,5—Balatonites sp. indet. II. *4*, M.C.Z. 5246, from loc. 167, Doi Chang shale and sandstone, Doi Chang, Thailand. ×1. *5*, M.C.Z. 5247, from loc. 168K, Hong Hoi shale and sandstone, Hong Hoi, Thailand.

6,7—Cladiscites cf. *C. beyrichi* Welter. M.C.Z. 5230, from loc. 151 which is either Hong Hoi or Doi Chang, Thailand. ×1.

8—Sturia sp. indet. M.C.Z. 5243, from loc. 168N, Hong Hoi shale and sandstone, Hong Hoi, Thailand. ×1.

9–14—Beyrichites sp. indet. M.C.Z. 5242, from loc. 167, Doi Chang shale and sandstone at Doi Chang, Thailand. ×1.

15–16—Tropigymnites cf. *T. chandra* (Diener). M.C.Z. 5244, from loc. 167, Doi Chang shale and sandstone, Doi Chang, Thailand. ×1.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

1

3

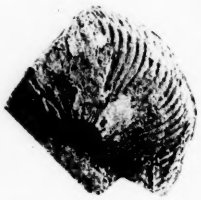
5

2

9

6

4



10

7

8

11

12

SYSTEMATIC DESCRIPTIONS

Family CLADISCITIDAE Zittel, 1884

Genus CLADISCITES Mojsisovics, 1879

CLADISCITES cf. C. BEYRICHI Welter

Pl. 83, fig. 6,7

Cladiscites beyrichi WELTER, 1914, Paläontologie von Timor, Lief. 1, p. 170, pl. 28, fig. 22; ARTHABER, 1928, Jaarb. Mijnw. Nederl. Ind., p. 24, pl. 1, figs. 1–4.

This well known and widely distributed Upper Triassic genus is represented in the collection by a single small immature specimen which can best be compared with *Cladiscites beyrichi* Welter from Timor. The specimen measures 31.5 mm. in diameter, 13.5 mm. in width of the last whorl, and 18 mm. in the height of the last whorl. The whorls are subquadrate in outline with slightly arched lateral flanks and venter and well rounded ventral shoulders. The shell bears delicate spiral strigations which appear to be equally developed on the flanks and venter. Only a portion of the suture in the ventral region is visible.

Remarks.—A large number of species of *Cladiscites* have been described, especially from the Tethyan geosynclinal region. The small size of this specimen, apparently an immature individual, prevents any detailed comparisons with most other known species. *Cladiscites* is known from Karnian and Norian formations.

Occurrence.—Locality 151 which Pitakpaivan (1955, p. 10) states is either Hong Hoi or Doi Chang.

Family TRACHYCERATIDAE Haug, 1894

Genus TRACHYCERAS Laube, 1869

Subgenus PARATRACHYCERAS Arthaber, 1914

TRACHYCERAS (PARATRACHYCERAS) cf. T. (P.) REGOLEDANUM (Mojsisovics)

Pl. 83, fig. 1–2; Pl. 84, fig. 10

Ammonites (Trachyceras?) regoledanus MOJSISOVICS, 1869, Jahrb. geol. Reichsanst. Wien, Bd. 19, p. 134, pl. 3, figs. 7,8.

Trachyceras regoledanum MOJSISOVICS, 1882, Abh. geol. Reichsanst. Wien, Bd. 10, p. 132, pl. 29, figs. 6,7,8; SIMIONESCU, 1913, Akad. Romana Public Vas. Adam. Bucarest., v. 34, p. 298,353, pl. 3, fig. 8.

Paratrachyceras regoledanum ARTHABER, 1914, Beitr. Pölaontologie Österr.-Ungarns u. des Orients, Bd. 27, p. 137, pl. 16, fig. 1.

Incomplete partial body chambers with a distinctive pattern of ribs are known from four localities. The specimens illustrated on Plate 1, figures 1,2, are the best preserved of the four and consist of the ventral half of the flank and the ventral region. Two of the other specimens are completely crushed specimens in a clay shale matrix. The fourth specimen is small, fragmentary, but uncrushed (Pl. 84, fig. 10).

The whorl section is compressed with broadly arched flanks which bear flat ribs that project forward near the venter. The ribs are much broader than the interrib spaces. The ribs cross the venter forming forward projected chevrons within a ventral furrow. The ribs are broadest near the ventral region of the flanks and narrow slightly

---

EXPLANATION OF PLATE 84

FIGS. *1,2*—*Ptychites* cf. *P. rectangulatus* Kraus. M.C.Z. 5235, from loc. 153, probably the Doi Chang shale and sandstone, Doi Chang, Thailand. ×1.

3–8—*Joannites* cf. *J. klipsteini* (Mojsisovics). *3,4,7,8*, U. S. Geological Survey, locality unknown but either Hong Hoi or Doi Chang, Thailand. *5,6*, M.C.Z. 5239, from loc. 171, horizon unknown but either Hong Hoi or Doi Chang, Thailand. ×1.

9—*Lobites* cf. *L. ellipticus* (Hauer). M.C.Z. 5238, from loc. 168c, Hong Hoi shale and sandstone, Hong Hoi, Thailand. ×1.5.

10—*Trachyceras* (*Paratrachyceras*) cf. *T.* (*P.*) *regoledanum* (Mojsisovics). M.C.Z. 5231, loc. 168A, Hong Hoi shale and sandstone, Hong Hoi, Thailand. ×1.5.

11–12—*Ptychites* cf. *P. rectangulatus* Kraus. M.C.Z. 5236, from loc. 167, Doi Chang shale and sandstone, Doi Chang, Thailand. ×1.

where they are projected forward and over the venter. One of the badly crushed specimens has a portion of the umbilical shoulder preserved, and the curvature of this shoulder indicates an involute specimen with a rather narrow umbilicus. No trace of a suture is present on any of the specimens.

Remarks.—As well as one can interpret these specimens, the main morphological features—that is the compressed whorl section, degree of involution, the nature of the ribs, the absence of nodes or tubercles and the grooved venter—indicate affinities to *Trachyceras* (*Paratrachyceras*). In most species of this genus the ventral groove is smooth, the ribs not crossing the venter. The only exception to this that I have been able to discover is the specimen described and illustrated by Arthaber (1914, p. 137, pl. 16, fig. 1) as *T.* (*Paratrachyceras*) *regoledanum* (Mojsisovics) from an Upper Ladinian horizon in Turkey. This specimen has the ribs passing over the venter in the same fashion as that of the Thailand specimen illustrated here on Plate 83, figures 1,2. Arthaber's specimen appears to be quite similar to the Thailand specimens in terms of conch shape, involution, and type of ribbing except that there are some nodes on the ribs. Other illustrations of this species, unfortunately, do not show the nature of the venter.

Occurrence.—Plate 83, figures 1,2, locality 167, Doi Chang shale and sandstone at Doi Chang; Plate 84, figure 10, locality 168a; unfigured specimens from locality 168h and 168g, M.C.Z. 5232 and 5233, Hong Hoi Shale and sandstone at Hong Hoi. The associated faunas from localities 168a,g,h clearly indicate an Upper Triassic age, probably Karnian. The associated fauna from locality 167 include such genera as *Beyrichites*, *Balatonites*, and *Ptychites* and indicate a Middle Triassic age, probably Anisian. It would appear that either the specimen from locality 167 is misidentified and not conspecific with those from locality 168, or there is an error in labeling of the specimen. The preservation and nature of the matrix of the specimen from locality 167 is similar to the other specimens from that locality.

Family PTYCHITIDAE Mojsisovics, 1882
Genus PTYCHITES Mojsisovics, 1875
PTYCHITES cf. P. RECTANGULATUS Kraus
Pl. 84, figs. 1,2,11,12

Ptychites rectangulatus KRAUS, 1916, Wiws. Mitt. aus Bosnien und der Herzegowina, Bd. 13, p. 25, 26, pl. 9, figs. 1a,b; RENZ, C., 1931, Praktika de l'Akad. d'Athènes, 6, p. 292; RENZ, C., 1931, Eclogae geol. Helvetiae, v. 24, p. 56; KUTASSY, 1933, Fossilium Catalogus, Pt. 56: Cephalopoda triadica 2, p. 641.

A large well-preserved specimen (Pl. 84, figs. 1,2) and two immature specimens, one of which is figured on Plate 84, figures 11,12, are representatives of the unusual group of subquadrate ptychitids. The larger specimen measures 72.0 mm. in diameter, 36.0 mm. for the width of the last whorl, and 38.0 mm. for the height of the last whorl. The umbilicus measures 14.0 mm. in diameter. The whorl section is subrectangular with broad, slightly arched lateral flanks, abrutply rounded umbilical shoulders, and more broadly rounded ventral shoulders. The venter is broad, and arched to a slight degree. The lateral flanks bear low radial folds that increase in breadth toward the venter where they attain their maximum size and then disappear at the ventral shoulder. There are 13 such folds visible, a complete volution probably had a total of 14 or 15 such folds. In addition to the radial folds there are faint radial growth lines. Only faint traces of the last suture are preserved.

The smaller specimens, which are here considered as immature form of the same species as the larger specimen, differ mainly in the higher arched venter; thus a more typical ptychitid outline. The radial folds are present but much reduced.

Remarks.—Species of *Ptychites* are extremely widespread, common, and typical of Middle Triassic formations throughout the world. Whereas the conch shape varies tremendously from compressed to even depressed forms, and there is likewise much variation in the pattern of ornamentations, the whorl sections are most generally rounded to compressed. Species with subrectangular whorl sections are indeed uncommon. These Thailand specimens appear to be most comparable to *Ptychites rectangulatus* Kraus (1916) from Anisian strata in the Volujak Alps of Yugoslavia. The whorl shape, involution, and pattern of ribbing are quite similar and perhaps these specimens are conspecific. However, on the basis of the data available it seems best to refrain from such an absolute correlation. The only

other subrectangular ptychitid to come to my attention is *P. dieneri* Gugenberger (1927) in another work on collections from the same fauna and localities as that studied by Kraus (1916) from Yugoslavia. *Ptychites dieneri* has subangular umbilical and ventral shoulders and flattened venter and lateral flanks. This species is likewise much more involute than either *P. rectangularis* or the Thailand specimens described here.

Occurrence.—Large specimen (Pl. 84, figs. 1,2) locality 153, exact position unknown, Pitakpaivan (1955, p. 10) concludes that this locality is definitely either Hong Hoi or Doi Chang. The map submitted to me by Dr. Sethaput indicates that locality 153 is in the Doi Chang shale and sandstone (Text-fig. 1). The small specimen (Pl. 84, figs. 11,12) and unfigured specimen M.C.Z. 5237, are from locality 167, Doi Chang shale and sandstone at Doi Chang, Thialand.

Genus STURIA Mojsisovics, 1882
STURIA sp. indet.
Pl. 83, fig. 8

A badly crushed completely involute ammonite with prominent spiral striae is assigned to this genus. The lack of precise information on the shape of the conch or the nature of the suture prevents comparisons at the specific level and may leave even this generic assignment open to question. On thorough examination of this specimen, I am convinced that there are no angular edges in the region of the venter but rather it is most probable that the conch was discoidal in shape with a rounded venter. The conspicuous spiral striae extends from the umbilicus over the whole area of the lateral flanks and across the venter.

A small fragment of the venter and a portion of the flanks of a body chamber with strigations are also present in the collections. This specimen is from locality 167 and is most likely a fragment of a larger specimen of *Sturia* and is indicated on the faunal list of locality 167 as *Sturia* sp. indet. II (M.C.Z. 5229).

Spiral striae over the whole whorl section is not a common feature on Triassic ammonites. This type of ornamentation is found on *Sturia* Mojsisovics, *Metasturia* Spath, *Psilosturia* Diener, *Romanites* Kittl, *Cladiscites* Mojsisovics, *Hypocladiscites* Mojsisovics, *Procladiscites* Mojsisovics, and *Psilocladiscites* Mojsisovics. As a family the Cladiscitidae are characterized by subquadrate whorl sections. *Romanites* has a conch like that of *Joannites* that is more or less discoidal but with no constrictions. This genus, however, so far as known is confined to the Karnian. The Thailand specimen comes from a horizon approximately equivalent to the beds containing *Balatonites* and thus is most probably Anisian in age. *Psilosturia* has the strigations confined to the periphery. This leaves only *Sturia* and *Metasturia* which have discoidal conchs and spiral strigations on the whole conch. These two genera differ mainly in the nature of the suture. *Metasturia* is known only from Yugoslavia, whereas *Sturia* has a wide distribution through Tethys, Timor, and Japan.

Occurrence.—Locality 168n, Hong Hoi shale and sandstone at Hong Hoi, Thailand; locality 167, Doi Chang shale and sandstone, at Doi Chang.

Family LOBITIDAE Mojsisovics, 1882
Genus LOBITES Mojsisovics, 1875
LOBITES cf. L. ELLIPTICUS (Hauer)
Pl. 84, fig. 9

Clydonites ellipticus HAUER, 1860, p. 128, pl. 5, figs. 12–14.
Lobites ellipticus MOJSISOVICS, 1875, Abh. geol. Reichsanst. Wien, Bd. 6, Heft. 2, p. 161–162, pl. 68, figs. 17–18; pl. 69, figs. 1–3; RENZ, Jahr. k. k. Geol. Reichsanst., Bd. 60, Heft. 3, 1910, pl. 19, fig. 3, pl. 22, figs. 1,3; RENZ, 1911, Palaeontographica, Bd. 58, p. 58, pl. 5, figs. 1,2, 4,6; SIMIONESCU, 1913, Akad. Romana Public Vas. Adam. Bucarest., v. 34, p. 324,362, pl. 5, fig. 5, pl. 6, fig. 2.

A single slightly crushed specimen with a portion of the shell preserved can be assigned to this very distinctive genus and whereas specific identification is not possible it appears to be most comparable with the type species *Lobites ellipticus*. The conch is occluded with pronounced and excentrumbilication of the outer volution. The whorls are elliptical in cross section, the venter being narrowly rounded. The lateral areas bear narrow, low, radial ribs that are extremely faint in the region of the umbilicus but become more pronounced toward the venter. The ribs appear to cross the venter. No suture is preserved.

Remarks.—Even though no suture is present on this specimen, the whorl shape, involution, excentrumbilication, and the ribbing are sufficient to clearly establish its identity, at least at the generic level. Likewise of the numerous species of *Lobites* described it is most closely similar to *L. ellipticus* (Mojsisovics, 1873, p. 161, pl. 68, figs. 17,18). By far the largest numbers of species are known from various Ladinian and Karnian localities in the Alps and adjacent regions. Only two incompletely known forms have as yet been recorded from the Himalayan Triassic (Diener, 1906). One of these forms Diener identified as *Lobites*, sp. ind. cf. *L. ellipticus* Hauer. This specimen is quite similar to the Thailand specimen but differs (as it does with *L. ellipticus*) in a slightly opened umbilicus, and in its curved ribs. Diener's specimen is from the *Tropites* limestone (Karnian) and is about the same size as the Thailand specimen.

The richly fossiliferous Upper Triassic of Timor has yielded only one species of *Lobites*, namely *L. brouweri* Arthaber (1928). This form is somewhat transitional to *Coroceras*. In western North America, McLearn (1937) has described one species, *Lobites pacianus* McLearn, from the *Nathorstites* fauna of the Peace River area, British Columbia. Two species of *Lobites*, *L. carinatus* and *L. gargantua*, have been described by Johnston (1941) from a lower Karnian horizon at New Pass, Nevada. These North American species are distinctive from the Thailand specimen.

Occurrence: Locality 168c, Hong Hoi shale and sandstone at Hong Hoi.

Family JOANNITIDAE Mojsisovics, 1882
Genus JOANNITES Mojsisovics, 1879
JOANNITES cf. J. KLIPSTEINI (Mojsisovics)
Pl. 84, figs. 3–8

Arcestes klipsteini MOJSISOVICS, 1875, Abh. geol. Reichsanst. Wien, Bd. 6, Heft. 2, p. 84, pl. 61, figs. 2,3, pl. 62, figs. 2,3.

Joannites klipsteini MOJSISOVICS, 1882, Abh. geol. Reichsanst. Wien, Bd. 10, p. 170; FRECH, 1907, p. 25, pl. 6, fig. 3; DIENER, 1908, India Geol. Survey Mem. Palaeontologie Indica, ser. 15, v. 5, no. 3, p. 42, pl. 5, fig. 8; DIENER, 1909, India Geol. Survey Mem. Paleontologie Indica, ser. 15, v. 6, no. 2, p. 8, pl. 2, fig. 1; RENZ, 1910, Jahr. k. k. Geol. Reichsanst., Bd. 60, Heft. 3, pl. 19, fig. 7; RENZ, 1911, Paleontographica, Bd. 58, p. 87; SIMIONESCU, 1913, Akad. Romana Public Vas. Adam. Bucarest., v. 34, p. 317, pl. 4, fig. 3, text-figs. 36,37; WELTER, 1914, Pälaontologie von Timor, Lief. 1, p. 194; ARTHABER, 1928, Jaarb. Mijnw. Nederl. Ind., 55, p. 101, pl. 16, fig. 2; JOHNSON, 1941, Jour. Paleontology, v. 15, p. 447.

Nine specimens of identical preservation from various localities (168a, 171, 151, and from an unknown locality but most probably one of the previous ones) are considered to be conspecific and most closely comparable to *Joannites klipsteini* (Mojsisovics). In all the specimens the conch is completely involute, smooth, compressed, with a broadly rounded venter. The largest specimen (diameter 66.3 mm.) illustrated on Plate 84, figures 3,4 has no constrictions, which are present on the other specimens. The next largest specimen (Pl. 84, figs. 5,6, diameter 60 mm.) has three constrictions on the outer whorl equally disposed around the volution. Two of the smaller specimens, diameters of 43 and 38.3 mm., have four constrictions on the last volution and one crushed specimen of 41 mm. diameter appears to have five constrictions. *Joannites* is another of the genera of Triassic ammonoids with a large number of species. In this case species have been established primarily on the basis of the number of constrictions per whorl and to some extent on the number of lateral lobes in the suture. Johnston (1941) has supplied a useful key for the identification of species on the number of constrictions and on the number of lateral lobes. Both of these morphological features, however, are highly variable and dependent on rates of growth and general development, factors as yet poorly understood. For this reason, plus the fact that the sample available is small and from various localities, specific determination is not advisable beyond indicating a close similarity to *J. klipsteini*.

Joannites ranges from the Anisian through the Karnian and is widely distributed through the region of Tethys in the Alpine region, the Himalayan, and Timor. It is likewise known from Karnian strata in Nevada. Of the nine specimens available, only that from locality 168a is from a known horizon and locality, where it is associated with *Trachyceras* (*Paratrachyceras*) cf. *T.* (*P.*) *regoledanum* Mojsisovics and overlies beds which contain *Holobia* sp. indet. and

Lobites cf. *L. ellipticus*. A Karnian age is suggested by this association. The same age is indicated for locality 151, where *Cladiscites* cf. *C. beyrichi* is recorded. The identity of these specimens both in terms of their morphology and preservation strongly suggests they came from an identical formation and horizon.

Occurrence. Plate 84, figures 3,4,7,8, locality unknown but either Hong Hoi or Doi Chang; the same applies to the specimen illustrated by Plate 84, figures 5,6 from locality 171 as it does to unfigured specimen from locality 151; the one precisely located specimen is from locality 168a, Hong Hoi shale and sandstone at Hong Hoi; this specimen is not illustrated but is identical to that illustrated on Plate 84, figures 7,8.

Family BEYRICHITIDAE Spath, 1934
Genus BEYRICHITES Waagen, 1895
BEYRICHITES sp. indet.
Pl. 83, fig. 9–14

Three fragmentary living chambers are considered to belong to an indeterminate species of *Beyrichites*. The whorl sections are compressed with slightly arched lateral areas converging toward a narrowly rounded venter. There are no distinct ventral shoulders; the umbilical shoulders, however, are sharply rounded and the umbilical wall nearly vertical. The lateral areas bear low, broad, slightly falcoid ribs. These ribs are narrowest in the region of the umbilicus and gradually widen to two or three times this width in the region of the ventral shoulders. There is no indication of nodes or thickening of the ribs in the area of the ventral shoulder, and the venter is smooth, rather the ribs merely broaden and graduate imperceptibly onto the smooth venter. This pattern of ribbing is especially marked on the specimens figured on Plate 83, figures 11–13, and only faintly present on the smaller fragment of Plate 83, figures 9, 10. Fragmentary remnants of the last suture are present on all of the specimens but these are not sufficient to give even a partial picture of the suture.

Remarks.—The three specimens described here are closely comparable to several of the forms described by Diener (1895) from the Himalayan Anisian as *Meekoceras*. At this time Diener recognized ten species of *Meekoceras* which on the basis of the descriptions and illustrations appear to be all closely related. The distinction between these species is expressed in slight differences in proportions and shape of the whorl section and the character of the lateral falciform ribs. The Thailand specimens are particularly close to "*Meekoceras*" *narada* Diener (1895, pl. 8, figs. 7a,b) "*M.*" *srikanta* Diener (1895, pl. 8, figs. 8a,b,9a,b) and even "*M.*" *proximum* Oppel (in Diener), 1895, pl. 8, figs. 2a,b,c). The differences between the Thailand specimens and these species lie mainly in the character of the ribs. It should be noted, however, that Diener based these species of "*Meekoceras*" on only one or two specimens for each specific group he established.

In 1907, Diener placed most of these Himalayan Anisian species of "*Meekoceras*" in the genus *Beyrichites*, but "*M.*" *nalikanta*, "*M.*" *srikanta*, and "*M.*" *narada* he interpreted as being more similar to the inner whorls of *Hollandites voiti* (Oppel) and as independent species of the genus *Hollandites*. This interpretation is not followed because of the extremely close relationship of these forms between themselves and all the other species placed without question in *Beyrichites*.

The genus *Beyrichites* is represented by a large number of species in the region of the western Tethys, as well as in the eastern Tethys—Himalayas and Timor. It is likewise known from Japan, British Columbia, and Nevada in the United States. A few species are known from uppermost Scythian beds on the Island of Chios, but the great majority of the known species are Anisian in age.

Occurrence.—Locality 167, Doi Chang shale and sandstone at Doi Chang, Thailand.

Family CELTITIDAE Mojsisovics, 1893
Genus TROPIGYMNITES Spath, 1951
TROPIGYMNITES cf. T. CHANDRA (Diener)
Pl. 83, fig. 15,16

Japonites chandra DIENER, 1895, India Geol. Survey Mem. Palaeontologie Indica, ser. 15, v. 2, no. 2, p. 33, pl. 10, fig. 4; DIENER, 1907, India Geol. Survey Mem. Palaeontologia Indica, ser. 15, v. 4, Mem. 2, p. 88.
Tropigymnites? chandra SPATH, 1951, Catalogue Fossil Cephalopoda British Museum (Nat.

Hist.). Part 5, The Ammonoidea of the Trias (II), p. 171.

A single specimen consisting of only one volution of living chamber with the phragmocone completely missing appears to be assignable to this genus and is most comparable to *Tropigymnites chandra* (Diener, 1895, p. 33–34, pl. 10, figs. 4a,b,c). Only one side of the living chamber but most of the venter is preserved. The specimen measures 48.7 mm. in diameter, the height of the last whorl measures 18 mm., and the width of the last whorl is approximately 11 mm. The umbilicus is 14.5 mm. in diameter. The whorls are compressed with slightly arched whorl sides, grading on to broadly rounded ventral shoulders that meet along a fairly sharp line producing a bluntly fastigate venter. The cast of the umbilical area is preserved and this clearly shows that the umbilical wall was approximately vertical and that there was a progressive increase in the size of the umbilicus. The whorls bear low, rather closely spaced radial ribs that extend to the fastigate venter. No suture is preserved.

Remarks.—The generic assignment of this particular specimen may be open to question since no trace of any suture is preserved. The general shape of the conch, degree of involution and low, radial ribs suggest the possibility of it being a species of *Anagymnites*, and quite similar to the type species of that genus, *A. lamarcki*. However, in the absence of the suture the deciding factor favoring assignment to *Tropigymnites* is the length of the body chamber which is on this specimen at least one volution in length. Body chambers of this length are not encountered within the Gymnitidae, and in particular *Anagymnites*, but are characteristic of the Celtitidae to which *Tropigymnites* belongs.

The few species now assigned to *Tropigymnites* had previously been assigned to *Sibyllites* (Hauer, 1896) and *Japonites* (Diener, 1895; Salopek, 1911; Reis, 1901). These include *Tropigymnites planorbis* (Hauer, 1896)—the type species—and *T. ganghoferi* (Reis, 1901) from Anisian beds in the Alps; *T. crnogorensis* (Salopek, 1911) from Anisian strata of Yugoslavia and Greece; and *T. chandra* (Diener, 1895) from Anisian formations of the Himalayas.

Whereas the Thailand specimen agrees well in most features of the conch morphology with *Tropigymnites chandra* and even to the type species *T. planorbis*, it differs in being more involute. The umbilicus in these species is about 50 percent the diameter of the conch but in the Thailand specimen the umbilicus appears to be a little more than 30 percent the diameter of the conch. In this respect there is more agreement to *Anagymnites*.

Occurrence.—Locality 167, Doi Chang shale and sandstone, at Doi Chang, Thailand.

Family BALATONITIDAE Spath, 1951
Genus BALATONITES Mojsisovics, 1879
BALATONITES sp. indet. I
Pl. 83, fig. 3

A single fragmentary portion of a living chamber is assignable to the genus *Balatonites* and is most probably most closely comparable to the type species *Balatonites balatonicus* (Mojsisovics, 1873, pl. 13, figs. 3a,b; 1882, pl. 4, figs. 2–6). The compressed whorl section with forward projecting ribs bearing nodes, and the fastigate venter upon which the lateral ribs continue, are characteristic features of this genus. The ornamented nature of the conch in this genus has led to the introduction of an abnormal number of species. In the Fossilium Catalogue, 47 species are recorded (Diener, 1915; Kutassy, 1933). As an example of the extreme splitting in this group, Arthaber (1896) recognized eight species plus three other separate groups not assigned new specific names because of incomplete data but thought to be separate taxa, from the Reiflinger limestone of Austria. This assemblage of species appears to be a rather homogeneous group differing mainly in the character of the ribbing, number of nodes, and features of the venter, a conclusion reached by Spath (1951, p. 15) previously.

Balatonites is mainly known from Anisian formations of the western Tethys region (the Alps and adjacent regions) plus the Muschelkalk strata of southern Germany. A few species of Ladinian age are also recorded from the Alpine region. Anisian formations of Nevada also contain species of *Balatonites*. Newton (1925) records and illustrates a specimen from the Malayan

Province of Kedah which he thought "bears some resemblance to the genus *Balatonites*." This particular specimen Spath (1951, p. 15) suggests may be "*Polycyclus*" *nasturtium* Mojsisovics but is definitely not a *Balatonites*. As best as can be told this Thailand specimen appears to be quite similar to *Belatonites lemoinei* (Mansuy, 1913) from northern Annam (Indochina). Mansuy's specimens are, however, as poorly preserved and incomplete as those recorded here from Thailand. The same comment on preservation applies to the *Balatonites* sp. figured by Patte (1922) from Yunnan, China.

Occurrence.—Locality 167, Doi Chang shale and sandstone at Doi Chang, Thailand.

BALATONITES sp. indet. II
Pl. 83, figs. 4,5

The two specimens described here clearly belong in *Balatonites* and could possibly be conspecific with the specimen described as *Balatonites* sp. indet. I. However, there is such a difference in the pattern of ribs and nodes that it is thought best to keep the groups separate. The specimens illustrated on Plate 83, figure 4, is partly cast and partly a mold preserved in a siltstone nodule. The opposite facing half of the specimen is in the collections. The most significant difference with the specimen illustrated on Plate 83, figure 3 is in the more subdued and narrower ribs, the lack of nodes on the ribs except at the umbilical and ventral shoulders. These differences, of course, could possibly be due to simple matters of stage of growth, that is, the specimen of Plate 83, figure 4, is a smaller, and presumably a younger, specimen than that represented by the whorl fragment illustrated in Plate 83, figure 3.

The second specimen is that illustrated on Plate 83, figure 5, which as can be seen is crushed and incomplete. The arrangement and character of the ribs suggest that this specimen is most probably identical with or closely related to that shown on Plate 83, figure 4.

General comments on the other species of *Balatonites* and their geologic distribution were given in the previous diagnosis.

Occurrence.—The specimen illustrated on Plate 83, figure 4, came from the locality 167, Doi Chang shale and sandstone at Doi Chang; the specimen illustrated on Plate 83, figure 5, came from Locality 168k, Hong Hoi shale and sandstone at Hong Hoi, Thailand.

REFERENCES

ARTHABER, GUSTAV VON, 1896, Die Cephalopodenfauna der Reiflinger Kalke: Beitr. Paläontologie Österr.-Ungarns u. des Orients, Bd. 10, Abt. 1,2.

——, 1914, Die Trias von Bithynien (Anatolien): Beitr. Paläontologie Österr.-Ungarns u. des Orients, Bd. 27, p. 85–206, pls. 11–18.

——, 1928, Ammonoidea Leiostraca aus der oberen Trias von Timor. 2, Nederl. Timor Expedite 1916 onder leiding von Dr. H. G. Jonker; Vitgegeven door Dr. H. A. Brouwer, IV: Jaarb. Mijnw. Nederl. Ind., 55, p. 1–174, pls. 1–20 (1926).

COX, L. R., 1936, On a fossiliferous Upper Triassic shale from Pahang, Federated Malay States: Ann. Mag. Nat. Hist., ser. 10, v. 17, p. 213–221, pl. 4.

DIENER, CARL, 1895, The cephalopods of the Muschelkalk: India Geol. Survey Mem. Palaeontologie Indica, ser. 15, v. 2, p. 1–118, pls. 1–31.

——, 1906, Fauna of the Tropites-Limestone of Byans: India Geol. Survey Mem. Palaeontologia Indica, ser. 15, v. 5, no. 1, p. 1–201, pls. 1–17.

——, 1907, The fauna of the Himalayan Muschelkalk: India Geol. Survey Mem. Palaeontologie Indica, ser. 15, v. 5, Mem. 2, p. 1–139, pls. 1–17.

——, 1908, Ladinic, Carnic and Noric Faunae of Spiti: India Geol. Survey Mem. Palaeontologie Indica, ser. 15, v. 5, no. 3, p. 1–157, pls. 1–24.

——, 1909, Himalayan Fossils. Fauna of the *Traumatocrinus* Limestone of Painkhanda: India Geol. Survey Mem. Palaeontologie Indica, ser. 15, v. 6, no. 2, p. 1–39, pls. 1–5.

——, 1915, Fossilium Catalogus, pt. 8, Cephalopoda Triadica: 369 p., W. Junk, Berlin.

HAUER, F. R., 1896, Beitrage zur Kenntniss der Cephalopoden aus der Trias von Bosnien. 2. Nautilen und Ammoniten mit ceratitischen Loben aus dem Muschelkalk von Haliluci bei Sarajevo: Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Bd. 63, p. 237–276, pls. 1–13.

GREGORY, J. W., 1930, Upper Triassic fossils from the Burmo-Siamese frontier. The Thaungyin Trias and description of corals: Records Geol. Survey India, v. 63, p. 155–167, pls. 1,2.

GUGENBERGER, ODOMAR, 1927, Die Cephalopoden des herzegowinischen Ptychiten-Kalkes der Stabljana—Alpe im Volujak—Geberge: Ann. Naturh. Museums Wien, Bd. 41, p. 97–149, pls. 2–6.

JOHNSTON, F. N., 1941, Trias at New Pass, Nevada (New Lower Karnic Ammonoids): Jour. Paleontology, v. 15, p. 447–491, pls. 58–71.

JONES, T. R., 1905, Note on a Triassic *Estheriella*

from the Malay Peninsula: Geol. Mag., 1905, decade 5, v. 2, no. 3, p. 50–52, pl. 2.

KRAUS, RICHARD, 1916, Die Cephalopodenfauna des Muschelkalkes der Volujak-Alpe bei Gacka in der Herzegowina: Wiss. Mitt. aus Bosnien und der Herzegowina, Bd. 13, p. 1–102, pls. 9–11.

KUMMEL, B., 1959, Anisian Ammonoids from Malaya: Breviora, no. 124, p. 1–8, pl. 1.

KUTASSY, A., 1933, Fossilium Catalogus, Pt. 56: Cephalopoda triadica 2, p. 371–832, Berlin.

LATOUCHE, T. H. D., 1913, Geology of the Northern Shan States: Mem. Geol. Surv. India, v. 39, pt. 2, p. 1–379, i–xli; pls. 1–27.

MANSUY, H., 1913, Paléontologie d L'Annam et du Tonkin: Mem. Serv. Geol. L'Indochine, v. 2, fasc. 3, p. 1–49, pls. 1–6.

MCLEARN, F. H., 1937, New species from the Triassic Schoolar Greek formation: Canadian Field Naturalist, v. 51, p. 95–98, pl. 1.

MOJSISOVICS, E. v., 1869, Über die Gliederung der oberen Triabildungen der ostlichen Alpen: Jahrb. geol. Reichsanst. Wien, Bd. 19, p. 91–150, pls. 2,3.

——, 1873, 1875, 1902, Das Gebirge um Hallstatt. 1, Abt. Die Cephalopoden der hallstatter Kalke: Abh. geol. Reichsanst. Wien, Bd. 6, Heft. 1,2 u. Bd. 1, Suppl.-Heft., p. 1–356, pls. 1–70 u. 1–23 (Heft. 1, p. 1–82, pls. 1–32, 1873; Heft. 2, p. 83–174, pls. 33–70, 1875; u. Suppl.-Heft., p. 175–356, pls. 1–23, 1902).

——, 1882, Die Cephalopoden der mediterranean Triasprovinz: Abh. geol. Reichsanst. Wien, Bd. 10, p. 1–322, pls. 1–94.

NEWTON, R. B., 1900, On Marine Triassic Lamellibranchiata discovered in the Malay Peninsula: Proc. Malac. Soc. London, v. 4, p. 130–135, pl. 12.

——, 1923, On Marine Triassic Shells from Singapore: Ann. Mag. Nat. Hist., ser. 2, v. 12, p. 300–321, pl. 9.

——, 1925, On Marine Triassic Fossils from the Malayan Provinces of Kedah and Perak: Geol. Mag., v. 62, p. 76–85, pl. 3.

PATTE, ETIENNE, 1922, Fossiles du Devonien et du Trias recueillis au Yunnan par M. Fromaget: Mem. Serv. Géol. L'Indochine, v. 9, fasc. 1, p. 37–57, pl. 3.

PIA, JULIUS, 1930, Upper Triassic fossils from the Burmo-Siamese frontier. A new Dasycladacea, *Holosporella siamensis* nov. gen., nov. sp., with a description of the allied genus *Aciculella* Pia: Records Geol. Survey India, v. 63, p. 177–181, pl. 4.

PITAKPAIVAN, KASET, 1955, Occurrences of Triassic formations at Mae Moh: Rept. Inv. 1, Royal Dept. Mines, Bangkok, p. 1–11, pls. 2–4.

REIS, O. M., 1901, Eine Fauna des Welterstein-kalkes. I. Cephalopoden: Geogn. Jahnesh., Bd. 12 (1900), p. 71–105, pls. 2–7.

RENZ, C., 1910, Stratigraphieche Untersuchungen im Griechischen Mesozoikum und Paläozoikum Jahr. k.k. Geol. Reichsanst., Bd. 60, Heft. 3, p. 421–636, pls. 18–22.

——, 1911, Die Mesozoischen Faunen Griechenlands: Palaeontgraphica, Bd. 58, p. 1–104, pls. 1–7.

——, 1931, Die Fauna der hydriotischen Bulogkalke: Praktika de l'Akad. d'Athènes, 6, p. 291–295, pl. 1.

——, 1931, Die Bulogkalke der Insel Hydra (Ostpeloponnes): Eclogae geol. Helvetiae, v. 24, p. 53–60.

SALOPEK, M., 1911, Uber die Cephalopodenfauen der Mittleren Trias von Süddalmatien und Montenegro: Abh. geol. Reichsanst. Wien, Bd. 16, p. 1–44, pls. 1–3.

SAURIN, E., 1956, Lexique Stratigraphique International, v. 3, Asie, Fasc. 62. Indochine, p. 1–141.

SAVAGE, H. E. F., 1950, Triassic fossils from near Kuala Lipis, Pahang: Colonia. Geol. and Min. Resources, v. 1, no. 1, p. 76–77.

SCRIVENOR, J. B., 1926, The Paleontology of British-Malaya: Jour. Malayan Branch, Royal Asiatic Soc., v. 4, p. 173–184.

SIMIONESCU, I. T., 1913, Les Ammonites Triasiques de Hagighiol (Dobrogea): Akad. Romana Public Vas. Adam. Bucarest., v. 34, p. 1–100, pls. 1–9.

SPATH, L. F., 1951, Catalogue of the Fossil Cephalopoda in the British Museum (Natural History). Part 5, The Ammonoidea of the Trias (II): London, p. 1–228.

TRAUTH, F., 1930, Upper Triassic fossils from the Burmo-Siamese frontier. On some fossils from the Kamawkala limestone: Records Geol. Survey India, v. 63, p. 174–176.

WELTER, O. A., 1914, Die Obertriadischen Ammoniten und Nautiliden von Timor: Palaontologie von Timor, Lief. 1, p. 1–258, pls. 1–36.

WEIR, JOHN, 1925, On some specimens of fossiliferous sandstone from Pahang, Malay Peninsula: Geol. Mag., v. 62, p. 347–350.

——, 1930, Upper Triassic fossils from the Burmo-Siamese frontier—Brachiopoda and Lamellibranchia from the Thaungyin River: Records Geol. Survey India, v. 63, p. 168–173, pl. 3.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 695–710, PLS. 85–90, JULY, 1960

OSGOOD (NIAGARAN) BRYOZOANS FROM THE TYPE AREA

T. G. PERRY AND DONALD E. HATTIN
Indiana University, Bloomington

ABSTRACT—A bryozoan faunule including 15 species has been collected from the upper 5 feet of the Osgood Formation (Niagaran) as exposed in the Southeastern Materials Corporation quarry in the SW¼, SW¼, sec. 22, T. 8 N., R. 11 E. at Osgood in Ripley County, Indiana. The following new species are established: *Ceramopora vesicularis*, *Fistulipora promiscua*, *Heterotrypa? perplexa*, *Cyphotrypa osgoodensis*, *Stigmatella dubia*, *Hennigopora apta*, and *Monotrypa exserta*. An unnamed species of *Trematopora* Hall is described. The bryozoans are associated with brachiopods, trilobites, corals, cystoids, nautiloids, and abundant arenaceous foraminifers. The fossils are embedded in gray highly calcareous shale that contains thin beds of gray coarse-grained argillaceous limestone.

The most abundantly represented genus is *Fistulipora* McCoy; specimens of this genus are assigned to the new species *Fistulipora promiscua* which displays considerable structural variability in tangential and longitudinal sections. The next most abundant genus is *Monotrypa* Nicholson which is represented by three species. Other bryozoan genera in this faunule include: *Ceramopora* Hall, *Cheilotrypa* Ulrich, *Heterotrypa?* Nicholson, *Cyphotrypa* Ulrich & Bassler, *Stigmatella* Ulrich & Bassler, *Hennigopora* Bassler, *Hallopora* Bassler, *Trematopora* Hall, *Diplotrypa* Nicholson, and *Pachydictya* Ulrich. *Stigmatella*, *Heterotrypa?*, and *Cyphotrypa* have not been reported previously from the Osgood. Specimens of fenestellid bryozoans are rare and poorly preserved.

INTRODUCTION

THIS paper describes a well preserved bryozoan faunule that has been collected mainly from the upper 5 feet of the Osgood Formation as exposed in the lower part of the Southeastern Materials Corporation quarry at Osgood, Ripley County, Indiana.

Members of the bryozoan genus *Fistulipora* McCoy constitute a major part of this bryozoan faunule. Species of this genus have not been recorded hitherto from the Osgood Formation in Indiana. This faunule is particularly significant because it was collected from the type locality of the formation (Foerste, 1897). The authors have visited more than 30 exposures of the Osgood in the vicinity of the type locality of the formation; only one of these, a natural exposure on Big Camp Creek in the NW¼, SW¼, sec. 25, T. 6 N., R. 10 E., from which a few specimens were collected, yielded bryozoans. Osgood exposures in Indiana generally are unfossiliferous or contain rare or fragmentary specimens. This faunule, therefore, is of further interest because of its rarity. The bryozoans were grouped first according to their zoarial form and external characters. Thin sections were then made of representative specimens of each group, and final assignment of the specimens into species was was accomplished by microscopic examination of internal structures as shown by thin sections.

Hitherto, knowledge of Osgood bryozoans was based largely on the studies of Bassler (1906). Although Bassler was concerned mainly with bryozoans from the Rochester Shale (Niagaran) of western New York and adjacent areas, he recorded 33 species which are common to both formations. In general, other geologists have either not noted bryozoans from the Osgood or have recorded them in a faunal list.

The faunule was collected mainly by the senior author and Paul C. Raymond while in the employ of the Indiana Geological Survey during the summer of 1953. The authors are grateful to T. A. Dawson and John B. Patton, of the Indiana Geological Survey, who read critically that part of the text concerned with the stratigraphy of the Osgood. R. S. Boardman, Associate Curator, Division of Invertebrate Paleontology and Paleobotany, United States National Museum, kindly lent the types of *Fistulipora lockportensis* Bassler for comparison with the new species *Fistulipora promiscua*. J. J. Galloway of Indiana University kindly assisted in certain generic and specific identifi-

cations. George Ringer of the Indiana Geological Survey took all photographs of thin sections that are used in the illustrations.

STRATIGRAPHY OF OSGOOD FORMATION

Name and definition.—Foerste (1896) introduced the name Osgood for beds that are exposed north of the town of Osgood, Ripley County, Indiana. He regarded these strata as "the Osgood phase of the Laurel formation." In the following year, Foerste (1897) assigned 15 to 25 feet of strata to the Osgood or "Cystidean beds" and indicated clearly that these beds lie between the overlying Laurel Limestone or "Cliff Rock" and the underlying "Clinton Limestone" (Brassfield Limestone of present usage). Although Foerste did not designate a type section for these strata, he stated, "The Osgood beds are named after Osgood, in the vicinity of which town the upper part of this formation has furnished many fossils."

The Indiana Geological Survey now considers the Osgood as a formation lying between the distinctive subjacent Brassfield Limestone (Albion) and the equally distinctive superjacent Laurel Limestone (Niagaran).

Distribution and thickness.—The Osgood Formation is recognized in Indiana, Ohio, Kentucky, and Tennessee.

In Indiana, the Osgood crops out in a belt that trends slightly east of north and extends from Clark County in the south to Wayne County in the north. In this area, the formation ranges from 13 to 23 feet in thickness. Foerste (1897, 1898) first established the areal distribution of the formation over a large area in southeastern Indiana.

According to Swartz and others (1942, pl. 1), Osgood is not used as a stratigraphic term in western Ohio. The Ohio Geological Survey, however, currently recognizes the Osgood in Preble County and eastward to Clark and Greene Counties (Bowman, 1955, personal communication).

On the west side of the Cincinnati Arch, in western Kentucky, the Osgood Formation can be traced as far south as Nelson County (McFarlan, 1943). Foerste (1935) stated that the formation could be followed still further southward into Marion County. In Jefferson County in northern Kentucky, the formation is about 30 feet thick and includes four units that are similar lithologically to the subdivisions of the Osgood that are recognized in southern Indiana (Butts, 1915).

In Tennessee, the Osgood Formation crops out on the west side of the Central Basin in a northeast-southwest-trending belt that extends from Macon to Hardin County, and in the Western Valley in Hardin and Decatur Counties (Wilson, 1949).

Lithology.—Foerste (1897) described three lithologic subdivisions of the Osgood Formation of southeastern Indiana. These units are, in ascending order, (1) Lower Osgood clay, (2) Osgood limestone, and (3) Upper Osgood clay. Foerste also described in this report (1897) a "basal Niagara limestone" but apparently did not regard this as a part of the Osgood Formation. This unit ranges up to 32 inches in thickness but is locally absent.

Cumings (1922) recognized four lithologic units in the Osgood. These are, in ascending order, (1) the lower Osgood limestone which is usually 8 to 15 inches thick but is absent locally, (2) the lower Osgood shale or clay

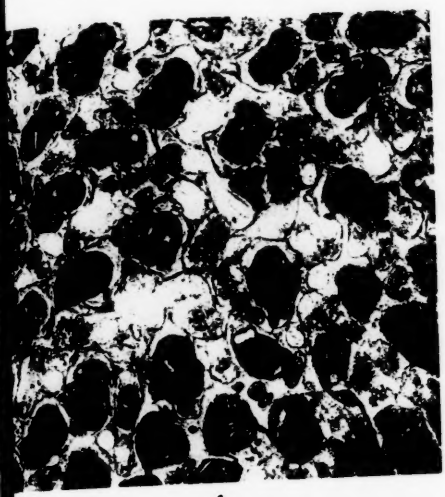
---

EXPLANATION OF PLATE 85

FIGS. *1–3*—*Ceramopora vesicularis* Perry & Hattin, n. sp. Holotype (Indiana Univ. Paleont. Coll. 5561) from Osgood Formation, Osgood, Indiana, each ×20. *1*, Tangential section showing vesicular nature of interzooecial area; *2*, longitudinal section; and *3*, tangential section displaying orientation of lunaria near a macula.

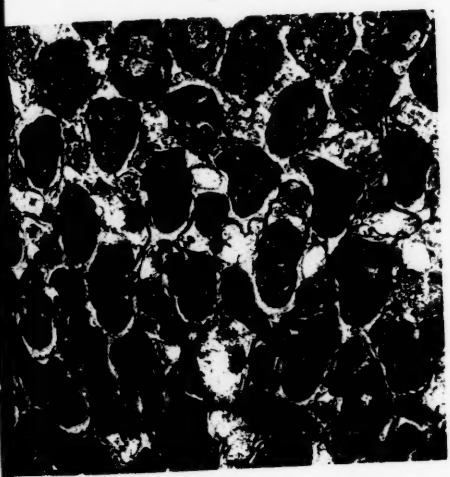
4—*Cheilotrypa ostiolata* (Hall). Hypotype (Indiana Univ. Paleont. Coll. 5566) from Osgood Formation, Osgood, Indiana, ×4. External view of zoarium that displays form of *C. coalescens* (Hall) and *C. ostiolata*.

5,6—*Ceramopora imbricata* Hall. Hypotype (Indiana Univ. Paleont. Coll. 5560) from Osgood Formation on Big Camp Creek, Ripley County, Indiana, each ×20. *5*, Tangential section showing distribution of interzooecial mesopores; and *6*, longitudinal section.



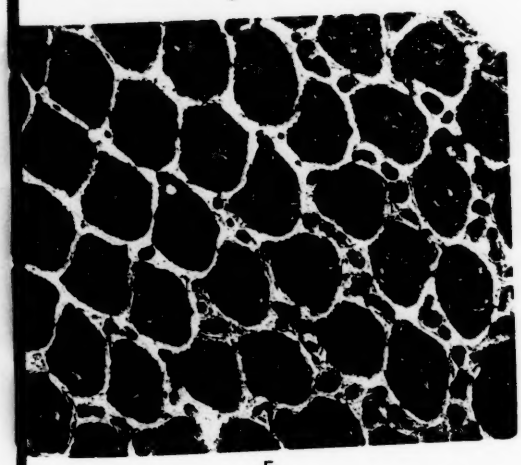
1

2



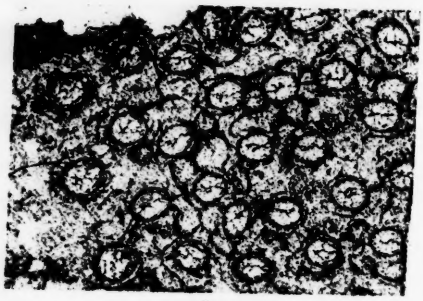
3

4

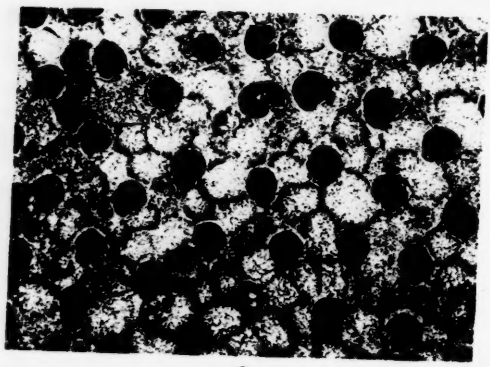


5

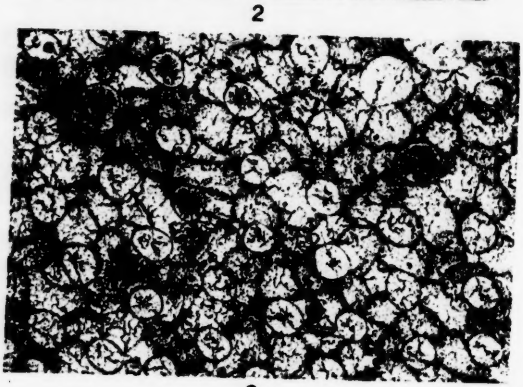
6



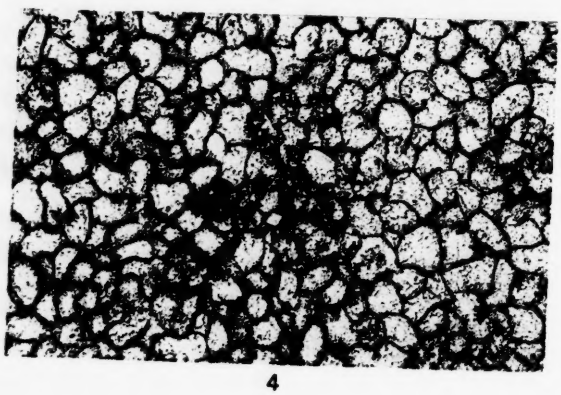
1



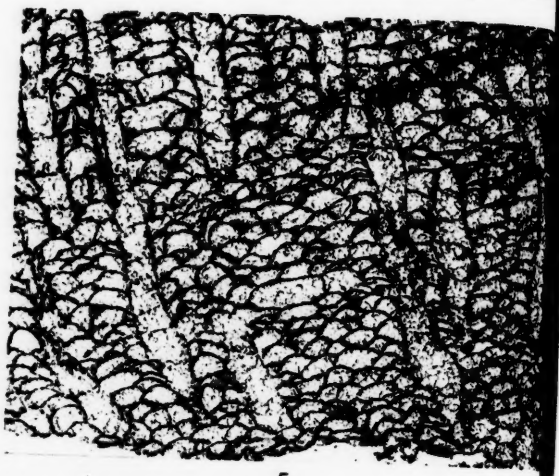
2



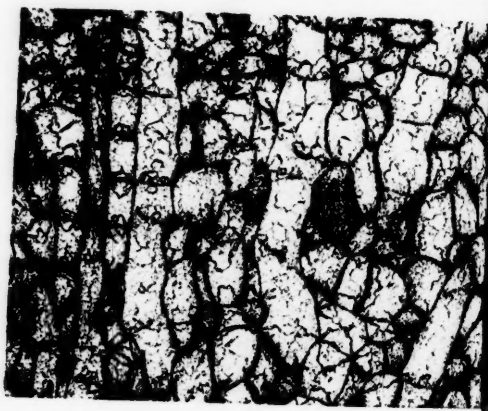
3



4



5



6

7

that is 11 to 16 feet thick, (3) the upper Osgood limestone which is 3 to 5 feet thick and may be crinoidal, and (4) the upper Osgood shale or clay that is 3 to 5 feet thick.

The Indiana Geological Survey currently recognizes four lithologic units in the Osgood Formation. These are, in ascending order, (1) gray argillaceous limestone, (2) gray knotty calcareous shale that contains some thin beds of limestone, (3) gray to buff crystalline thin-bedded limestone, and (4) gray soft shale. Although these four units are typical of the formation, they are not everywhere represented.

The upper 5 feet of the Osgood in the bottom of the Southeastern Materials Corporation quarry at Osgood, Indiana, consists of gray highly calcareous shale that contains thin beds of gray coarse-grained argillaceous limestone. Fossils described in this report are mainly from the shale beds.

Stratigraphic relations.—The Osgood overlies the Brassfield Limestone with disconformity. This relationship is indicated by (1) the inconsistency in thickness of the Brassfield which is absent locally, (2) pebbles of Brassfield Limestone in the overlying basal Osgood beds, and (3) the absence of rocks of late Albion and early Niagaran age from northern Tennessee to southern Indiana.

Fauna.—Most Osgood exposures in Indiana contain few identifiable fossils. Most exposures, even in the type area, either lack fossils or yield rare or fragmentary remains. The formation is sparsely fossiliferous in Kentucky (McFarlan, 1943), Tennessee (Wilson, 1949), and Ohio (Foerste, 1935; Stout, 1941). Nevertheless, Bassler (1915) listed more than 100 species from the Osgood; the genus *Holocystites* Hall is supposedly represented by 36 species. The faunal list compiled by Bassler included species from all areas of outcrop and, according to Cumings (1922), some of the listed species may have come from the Laurel Limestone (Niagaran). Some of the more common Osgood species have been described from the Waldron Shale (Niagaran) by Hall (1882).

Arenaceous Foraminifera from the Osgood have been studied by Stewart & Priddy (1941) and Dunn (1942). More recently, Raymond (1955, Table 1) has listed the following species of arenaceous Foraminifera from the Osgood Formation as exposed in the lower part of the Southeastern Materials Corporation quarry at Osgood, Indiana:

Ammodiscus exsertus Cushman
A. incertus (d'Orbigny)
A. minuta Dunn
Bifurcammina parallela Ireland
Glomospira cf. *G. siluriana* Ireland
Hyperammina harrisi Ireland
Lagenammina stilla Moreman
Lituotuba elongata Dunn
L. exserta Moreman
L. inflata Ireland
Psammosphaera cava Moreman
P. excerpta Dunn
Sorosphaera osgoodensis Stewart & Priddy
S. tricella Moreman
Thurammina arcuata Moreman
T. elliptica Moreman
T. foerstei Dunn
T. sp. indet.
Webbinella gibbosa Ireland
W. quadripartita Moreman

Boyce (1956) studied the Osgood fauna, exclusive of Bryozoa and Foraminifera; the great majority of his material was collected

---

EXPLANATION OF PLATE 86

FIGS. *1,7*—*Cheilotrypa ostiolata* (Hall). Hypotypes (Indiana Univ. Paleont. Coll. 5566) from Osgood Formation, Osgood, Indiana, each ×20. *1*, Tangential section showing dense interzooecial calcite of mature region; and 7, longitudinal section displaying axial canal.

2,6—*Fistulipora promiscua* Perry & Hattin, n. sp. Holotype (Indiana Univ. Paleont. Coll. 5562) from Osgood Formation on Big Camp Creek, Ripley County, Indiana; paratypes (Indiana Univ. Paleont. Coll. 5563, 5564) from Osgood Formation, Osgood, Indiana, each ×20. *2*, Tangential section of paratype (5564) showing very pronounced lunaria; *3*, tangential section of paratype (5563) showing very poorly developed lunaria, coarse vesicles, and wide range in zooecial diameter; *4*, tangential section of holotype showing fairly pronounced lunaria and abundant vesicles; *5*, longitudinal section of holotype showing thin interlocking vesicles; and *6*, longitudinal section of paratype (5563) showing coarse, vertically elongated vesicles.

from the upper 5 feet of the formation as exposed in the Southeastern Materials Corporation quarry at Osgood, Indiana. Boyce (1956, Table 1) identified the following species from the Osgood:

Anthozoa
Ditoecholasma acutiannulatum Amsden
Duncanella borealis Nicholson
Enterolasma caliculum (Hall)
Favosites cristatus var. *major* Davis
F. discoideus (Roemer)
F. forbesi var. *occidentalis* Hall
Striatopora flexuosa Hall

Brachiopoda
Atrypa nodostriata Hall
A. reticularis (Linnaeus)
A. reticularis var. *newsomensis* Foerste
Atrypina disparilis (Hall)
Barrandella fornicata (Hall)
Camarotoechia pisa (Hall & Whitfield)
Cyrtia exporecta (Wahlenberg)
Dictyonella cf. *D. corallifera* (Hall)
Dolerorthis flabellites (Foerste)
D. interplicata (Foerste)
Eospirifer eudora (Hall)
E. foggi (Nettelroth)
E. niagarensis (Conrad)
E. radiatus (Sowerby)
Howellella crispus var. *simplex* (Hall)
Leptaena rhomboidalis (Wilckens)
Meristina rectirostris (Hall)
Nucleospira pisiformis (Hall)
Orthostrophia fissistriata (Foerste)
Parmorthis waldronensis (Foerste)
Plectodonta elegantula (Hall)
P. transversalis (Wahlenberg)
Protomegastrophia profunda (Hall)
Rhynchotreta americana (Hall)
Whitfieldella intermedia (Hall)
W. nitida (Hall)

Gastropoda
Loxonema? sp.
Platyceras niagarense (Hall)
Platyostoma brownsportense (Foerste)
P. niagarense (Hall)

Nautiloidea
Dawsonoceras americanum (Foord)

Trilobita
Bumastus ioxus (Hall)
Calymene celebra Raymond
Dalmanites limulurus (Green)

Cystoidea
Caryocrinites bulbulus (Miller & Gurley)
C. ellipticus (Miller & Gurley)
C. indianensis (Miller)
Holocystites cf. *H. faberi* Miller
H. ornatus Miller
H. parvulus Miller
H. perlongus Miller
H. splendens Miller & Gurley

Blastoidea
Stephanocrinus elongatus Miller
S. gemmiformis Hall

Crinoidea
Pisocrinus gemmiformis Miller

Previous workers, except Bassler (1906), have given little or no attention to Osgood bryozoans.

Age and correlation.—The correlation of the Osgood has received considerable attention; the authors here refer only to the more significant papers on this subject.

Bassler (1906) has correlated the Osgood "chiefly if not exactly" with the Rochester Shale (Niagaran) of New York and adjacent areas; of the 80 bryozoan species which Bassler recognized in the Rochester, 33 are found also in the Osgood (Bassler, 1906). In 1942, however, Swartz and others (Pl. 1) equated the Osgood with the Rochester Shale and the underlying Irondequoit Limestone of western New York. Such correlation is partially in accord with the following statement made by Foerste (1904): "It (the Osgood fauna, authors' addition) corresponds to the reef fauna at the top of the Clinton of New York, where it occurs in the limestones exposed in lens-like cross-sections just beneath the Rochester shale." Butts (1915) supported the correlation of the Kentucky Osgood with the Rochester Shale of New York, as did Foerste (1931). At this time Foerste also stated (p. 178) that "The nearest approach to the Osgood formation on the east side of the Cincinnati anticline appears to be the Bisher formation. . . ."

Boyce (1956) has demonstrated that the Osgood correlates, at least in part, with the Rochester Shale and states:

> The results of my study show that the Osgood formation is correlative, at least in part, with the Rochester shale. . . . Of the 52 species found in the Osgood, 24 are also common to the Rochester shale. The greatest similarity between the two faunas is exhibited by the brachiopods. Faunal evidence is inconclusive regarding any possible correlation of the Osgood with the Irondequoit limestone. Fourteen species are found in the Irondequoit that have also been identified in the Osgood. Unfortunately, all these species are long ranging and of little value in detailed correlation."

Correlation of the Osgood Formation and

Rochester Shale on the basis of Foraminifera is not feasible because of lack of knowledge concerning the foraminiferal fauna of the Rochester. Raymond (1955, Table 1) has established that the arenaceous foraminiferal fauna of the Osgood most closely resembles the Chimneyhill Limestone (Albion) fauna of Oklahoma. The authors, however, are not favorably impressed with the usefulness of arenaceous Foraminifera for correlation studies because many species of these Foraminifera are long ranging and not well defined.

In summation, paleontologic evidence supports correlation of the Osgood Formation, at least in part, with the Rochester Shale. The soundness of this correlation is enhanced because it is based on two distinct studies, *viz.* consideration of bryozoans and consideration of brachiopods, corals, trilobites, gastropods, nautiloids, cystoids, blastoids, and crinoids.

SYSTEMATIC DESCRIPTIONS

Order CYCLOSTOMATA

Family CERAMOPORIDAE Ulrich, 1882

Genus CERAMOPORA Hall, 1851

CERAMOPORA IMBRICATA Hall, 1852

Pl. 85, figs. 5,6

Cerampora imbricata HALL, 1852, Paleontology New York, v. 2, p. 169, pl. 40e, figs. 1a–i; ULRICH, 1890, Illinois Geol. Survey, v. 8, p. 463, pl. 39, figs. 1-b; GRABAU, 1901, New York State Mus., Bull. 45, p. 163, fig. 58; GRABAU, 1901, Buffalo Soc. Nat. Science, Bull. 7, p. 163, fig. 58; BASSLER, 1906, U. S. Geol. Survey, Bull. 292, p. 19, pl. 6, figs. 1–10; GRABAU & SHIMER, 1907, North American Index Fossils, v. 1, p. 121, fig. 181; SHIMER & SHROCK, 1944, Index Fossils of North America, p. 253, pl. 96, figs. 12–14; BASSLER, 1953, p. G81, fig. 43, 1a–d.

External description.—Zoarium thin, discoidal, gently convex upward, with shallowly concave base; single broken specimen 37 mm. in maximum diameter and 4.3 mm. in greatest thickness; upper surface uneven. Zooecia closely crowded, mostly with rhombic outline, arranged en echelon in rows radiating and multiplying outward from maculae. Apertures bear inconspicuously elevated, acutely arched lunaria opening away from the maculae. Maculae small, rather inconspicuous, 6 to 7 mm. apart, and surrounded by zooecia of somewhat larger than average size.

Internal description.—In tangential section, zooecia typically rhombic or ovate, less commonly polygonal or irregularly shaped; average maximum zooecial diameter (based on 15 measurements) 0.61 mm., ranging from 0.49 to 0.77 mm.; average zooecial wall thickness (based on 20 measurements) 0.06 mm., ranging from 0.04 to 0.09 mm.; two and one-half or three zooecia in 2 mm. (based on 7 measurements), measuring parallel to long axes of zooecia. Zooecia generally in contact except in maculae where ovate zooecia separated by mesopores that may be isolated or loosely arranged in irregular rows. Lunaria generally weak or indistinct in regions lacking mesopores; in maculae, lunaria form distinct thickenings at proximal ends of zooecia and occupy as much as one-half the maximum zooecial diameter. Maculae characterized by abundant mesopores.

In longitudinal section, zooecia nontabulated, with nearly parallel somewhat irregular walls. Zooecial wall not of uniform thickness, perforated by scattered communication pores. Zoarium bilaminate, zooecia of one layer oblique to those of the other. A thin layer of vesicles at base of upper lamina presumably comprises initial growth stage of younger part of specimen. Zooecia intersect zoarial surface obliquely.

Remarks.—Our specimen is much larger than any of this species described previously and exhibits bilaminate growth. In other respects it closely resembles *Ceramopora imbricata* Hall, especially in zoarial form, size and arrangement of zooecia, nature of lunarium, presence of basal vesicular growth, arrangement of mesopores, and character of maculae. The central macula is not well preserved on our specimen. The basal vesicular layer in the younger lamina seemingly indicates that a new or rejuvenated colony has grown upon the older one. Bassler (1906) reports abundant *C. imbricata* Hall in the Osgood Formation at Osgood, Indiana.

CERAMOPORA VESICULARIS

Perry & Hattin, n.sp.

Pl. 85, figs. 1–3

External description.—Zoarium discoidal, gently convex upward with shallowly concave base; single broken specimen 26.2 mm.

in greatest diameter and 3.8 mm. in maximum thickness. Zooecia mostly ovate or elongate-ovate, arranged with long axes radiating from maculae. Lunaria moderately distinct and opening away from maculae.

Internal description.—In tangential section, zooecia generally ovate to elongate-ovate, less commonly nearly circular or of highly irregular outline, ranging from 0.42 to 0.64 mm. in maximum diameter and averaging 0.51 mm. for 20 measurements. Two and one-half to four zooecia in 2 mm., measuring parallel to long axes of zooecia. Zooecial wall thickness ranging from 0.04 to 0.07 mm., averaging 0.04(5) mm. for 20 measurements. Zooecial walls perforated by scattered generally inconspicuous communication pores. Zooecia commonly in contact but usually separated by mesopores of circular to highly irregular outline, ranging in size from less than 0.05 mm. to more than 0.6 mm. in greatest dimension. Maculae characterized by concentration of large highly irregular mesopores. Zooecia generally elongated radially from maculae. Lunaria most conspicuous in macular areas, generally forming distinctive thickenings of the proximal sides of the zooecial walls, occupying from one-third to one-half or more of zooecial circumference, and with extremities commonly indenting, but not projecting into, zooecial wall.

In longitudinal section, zooecia nontabulated, meeting the zoarial surface progressively more obliquely toward edge of colony. Walls are smooth to irregular, not of uniform thickness, and of indefinite structure.

Remarks.—Our specimen is somewhat abraded so that surficial features are not well preserved. This discoidal species has the indefinite wall structure, large irregularly shaped zooecia radiating from maculae, and communication pores that characterize the genus *Ceramopora* Hall. *C. vesicularis* differs from *C. niagarensis* Bassler, to which it is seemingly most closely related, in having lunaria that do not project into the zooecial cavity, zooecia that intersect the surface much more obliquely, and in having larger and more numerous mesopores. Our species differs from *C. imbricata* Hall because it lacks a basal spongy layer of vesicles, shows much greater range in size and shape of mesopores, displays far more numerous mesopores, has zooecia that are more generally ovoid than rhombic, and has a much more pronounced lunarium.

The species is named because the large number of mesopores imparts a vesicular appearance to the tangential section.

Family FISTULIPORIDAE Ulrich, 1882
Genus FISTULIPORA McCoy, 1850
FISTULIPORA PROMISCUA
Perry & Hattin, n.sp.
Pl. 86, figs. 2–6

External description.—Zoarium a unilaminate sheetlike expansion, up to 90 mm in greatest dimension, which may become convoluted forming hollow mud-filled masses; thickness of zoarial growth ranges from 1 to 12 mm. Low monticules or maculae sparsely developed, irregularly spaced, and consisting of vesicles flanked by zooecia somewhat above average in size. Lunaria obsolete to moderately conspicuous and usually more prominent on zooecia flanking monticules.

Internal description.—In tangential section, zooecia subround to pyriform, thin-walled, and irregularly spaced but very rarely in contact; maximum zooecial diameter, including lunarium, ranges from 0.20 to 0.38 mm., averaging 0.27 mm. for 150 measurements; most commonly four entire zooecia and part of fifth in 2 mm.; commonly five entire zooecia in this distance; uncommonly four entire zooecia or five entire zooecia and part of sixth in 2 mm.; rarely three complete zooecia and part of fourth or six entire zooecia in this length. Lunarium of variable development, ranging from nearly obsolete to conspicuous; where prominent, lunarium generally forms from one-quarter to nearly one-half of maximum zooecial diameter but does not project into zooecia. Adjacent zooecia very rarely in contact, generally separated by one or two, less commonly by three, polygonal vesicles ranging from somewhat larger than a typical zooecium to less than one-quarter the size of a zooecium; interzooecial distance ranges from 0.09 to 0.33 mm., averaging 0.21 mm. for 161 measurements. Monticules consisting of irregularly sized vesicles flanked by zooecia somewhat above average in size and with lunaria directed toward the center of the monticule.

In longitudinal section, zooecia erect, thin-walled, and containing as many as eleven, usually two to six, diaphragms per zooecium; diaphragms lacking in some zooecia. Interzooecial tissue highly variable, ranging from coarse, loosely interlocking, vertically elongated vesicles to thin, crescentic, compactly interlocking vesicles convex outward; vesicles at base of zoarium usually above average in size and highly convex outward; alternating bands of large and small vesicles, presumably reflecting variations in growth rate due to fluctuating environmental conditions, common.

Remarks.—The authors (1955, p. 1695, 1696) formerly assigned the 48 sectioned specimens, now comprising *Fistulipora promiscua*, to six species according to the prominence of the lunarium and the nature of the interzooecial tissue as shown in tangential section. Further study has convinced us that all of the specimens must be considered conspecific. The species includes forms which have subround zooecia with obsolete barely discernible lunaria and other specimens which have pyriform zooecia whose lunaria are so pronounced that they make up one-quarter to approximately one-half of the maximum zooecial diameter; many specimens show lunaria between these extremes of development. Similarly, specimens having large vesicles, as observed in tangential section, are conspecific with those in which vesicles are conspicuously smaller; many specimens show vesicles of intermediate size. Further, specimens which display poorly developed lunaria generally have large coarse vesicles that are elongated vertically in longitudinal section. In contrast, specimens showing well developed lunaria have conspicuously smaller vesicles that are thin, densely packed, and closely interlocked in longitudinal section. Because the sectioned specimens illustrate a gradational series with respect to the development of the lunarium and the size of the vesicles, we regard them as conspecific. Allocation of these specimens to arbitrarily defined species would serve no useful stratigraphic purpose, and such species could probably not be differentiated with certainty by other paleontologists.

Specimens of *Fistulipora promiscua* having poorly developed lunaria are reminiscent of *F. lockportensis* Bassler. We have examined thin sections of the holotype and paratype of the latter species and made the following measurements: Average maximum zooecial diameter 0.33 mm., ranging from 0.28 to 0.38 mm. for 20 measurements; and average interzooecial distance 0.22 mm., ranging from 0.12 to 0.31 mm. for 21 measurements. Twenty measurements of the number of zooecia in 2 mm. made on the type slides showed that typically (13 of 20 measurements) four entire zooecia occupy a 2-mm. distance; less commonly (5 of 20 measurements) four complete zooecia and a part of a fifth in 2 mm.; and rarely (2 of 20 measurements) three entire zooecia and a portion of a fourth in this distance.

The specific name alludes to the looseness or variability in structure shown by members of this species.

Genus CHEILOTRYPA Ulrich, 1884

CHEILOTRYPA OSTIOLATA (Hall), 1852

Pl. 85, fig. 4; Pl. 86, figs. 1,7

Trematopora ostiolata HALL, 1852, Paleontology New York, v. 2, p. 152, pl. 40A, figs. 5a–m; NICHOLSON, 1875, Paleontology Prov. Ontario, p. 60, fig. 26.

Trematopora coalescens HALL, 1852, Paleontology New York, v. 2, p. 150, pl. 40a, figs. 2a,b.

Cheilotrypa ostiolata (HALL), ULRICH, 1884, Jour. Cincinnati Soc. Nat. Hist., v. 7, p. 49, 50, pl. 3, figs. 7,7a; MOORE *et al.*, 1952, Invertebrate Fossils, p. 167, figs. 5–6, 5a,b; BUGE, 1952, *in* PIVETEAU, Traité de Paléontologie, p. 707, fig. 67.

Chilotrypa ostiolata (HALL), SIMPSON, 1895, 14th Ann. Rept., State Geol. New York, pl. 21, figs. 1,2; GRABAU, 1901, New York State Mus., Bull. 45, p. 164, fig. 60; GRABAU, 1901, Buffalo; Soc. Nat. Sci., v. 7, p. 164, fig. 60; BASSLER, 1906, U. S. Geol. Survey, Bull. 292, p. 24, pl. 8, figs. 11–15, pl. 9, figs. 1–4; GRABAU & SHIMER, 1907, North American Index Fossils, v. 1, p. 125, figs. 184a,b; SHIMER & SHROCK, 1944, Index Fossils of North America, p. 255, pl. 96, figs. 27–29.

External description.—Zoarium ramose, erect, with cylindrical branches and flared base; distal part of zoarium may be frondescent and anastamosing. Zoarial surface generally smooth, interrupted locally by short blunt branches some of which have terminal concavity marking axial canal. Zooecia mostly oval but commonly circular, not of uniform size, irregularly distributed, closely crowded on some specimens, surrounded by conspicuous slightly elevated peristomes

that are higher at lunarial side. Lunaria distinct, generally opening away from maculae. Maculae sparse, slightly depressed, and surrounded by zooecia of above average size.

Internal description.—In tangential section, zooecia oval, thick-walled, ranging from 0.22 mm. to 0.34 mm. in maximum zooecial diameter and averaging 0.27 mm. for 20 measurements. Four to six zooecia in a 2-mm. distance, measuring parallel to the maximum zooecial diameter. Interzooecial distance ranges from 0.08 to 0.32 mm., averaging 0.19 mm. for 57 measurements. Lunarium generally inconspicuous, not indenting zooecial cavity, usually represented by somewhat thicker walls, and occupying less than one-half the zooecial circumference. Interzooecial spaces filled with dense calcareous deposit that nearly obliterates vesicles; generally one, less commonly two, vesicles between adjacent zooecia. Maculae appear as relatively broad areas lacking zooecia.

In longitudinal section, axial region occupied by irregularly pinching and swelling canal. Nontabulated zooecia vertical in central region adjacent to axial canal, turning rather abruptly outward, and intersecting zoarial surface somewhat obliquely. Interzooecial space in mature region occupied by numerous thin vesicles occurring in single or imbricating rows; vesicles near surface filled with deposit of dense calcite.

Transverse sections characterized by conspicuous axial canal ranging from 0.29 to 0.90 mm. in maximum width; canal surrounded by usually coarse mud-filled zooecial tubes of immature region. Stellate appearance generally imparted where zooecial tubes have been cut at angles of deflection. Outward from this central region, zooecial tubes disposed radially and separated by coarse vesicles in early mature area and thin vesicles in late mature region.

Remarks.—In slightly oblique longitudinal sections, the zooecia of the immature region have a coarsely vesicular appearance. The dense stereom of the mature region mentioned by earlier authors may be a dense filling of the vesicles by calcite.

Bassler (1906) calls attention to the synonymy of *Cheilotrypa ostiolata* (Hall) and *C. coalescens* (Hall), claiming that the latter appears to be the basal part of the former. We concur that *C. ostiolata* is a synonym of *C. coalescens* because our finest specimen has regions characteristic of each "species." The *C. coalescens* portion is not basal, however, but occupies distal parts of the colony. We follow Bassler in hesitating to abandon the well known and widely used name *C. ostiolata* for the obscure *C. coalescens.*

Order TREPOSTOMATA
Family HETEROTRYPIDAE Ulrich, 1890
Genus HETEROTRYPA Nicholson, 1879
HETEROTRYPA? PERPLEXA
Perry & Hattin, n.sp.
Pl. 87, figs. 4–6

External description.—Fragment of ramose zoarium 16 mm. long and 4 mm. in diameter; surface weathered, not showing monticules or maculae.

Internal description.—In tangential section, zooecia subround to subangular, typically with moderately thick fibrous amalgamate walls; locally and rarely zooecial walls obscurely integrate; typically (6 of 10 measurements) seven entire zooecia and part of eighth in 2 mm., measuring parallel to length of zoarium; commonly (3 of 10 measurements) six entire zooecia and part of seventh in this distance; and rarely (1 of 10 measurements) eight complete zooecia and part of ninth in 2 mm. Acanthopores small, locally somewhat inflecting, numerous, three to nine, usually five to seven, associated with each zooecium. Mesopores common, subangular to subround, generally one-fifth to nearly one-half the size of a typical zooecium, and occurring singly or in groups of two or three. Two clusters of five or six zooecia, each somewhat above average in size, may represent monticules or maculae.

In longitudinal section, zoarium displays rejuvenation. Zooecia in outer growth layer contain as many as four diaphragms, usually one to three, per zooecium; zooecial walls in this layer mildly flexuous and consisting of arched laminae moderately convex outward; zooecia in inner layer have somewhat thinner walls and more numerous diaphragms spaced from one to one and one-half zooecial diameters apart. Mesopores rare in outer layer, not definitely recognizable in inner layer, not closely tabulate, and not traceable through total thickness of either zoarial layer. Acanthopores not observed.

Remarks.—The well developed plane of rejuvenation in the single representative of this species suggests, on first examination, that one bryozoan has encrusted another. In a small area in the longitudinal section, however, the plane of rejuvenation has nearly deteriorated, and here zoarial development presumably has been virtually continuous.

Interpretation of the longitudinal section is puzzling because, judging from the tangential section, it would expectably show many tabulated mesopores; such is not observed. The rarity of these structures in longitudinal section may suggest that the smaller cells in tangential section perhaps should be interpreted as small newly formed zooecia. Such an interpretation does not seem plausible because of the abundance of the smaller cells.

Assignment of this species to the genus *Heterotrypa* Nicholson is made with considerable hesitancy. Acanthopores in *H.? perplexa* are more numerous and smaller than in other species of *Heterotrypa*. Further, this genus has hitherto been confined to rocks of Ordovician age (Bassler, 1953). If the smaller cells in tangential section are young zooecia and not mesopores, as here interpreted, and if the specimen has not undergone rejuvenation, as here considered, but represents one bryozoan encrusting another, then the encrusting form may possibly be assigned to *Cyphotrypa* Ulrich & Bassler.

Genus CYPHOTRYPA Ulrich & Bassler, 1904

CYPHOTRYPA OSGOODENSIS
Perry & Hattin, n. sp.
Pl. 87, figs. 1–3

External description.—Zoarium free, hemispherical, up to 6 mm. thick and 16 mm. in diameter, or a laminate growth, having a maximum observed thickness of 7 mm., encrusting other fossils. Surface weathered, not revealing monticules or maculae, but locally showing slightly projecting acanthopores.

Internal description.—In tangential section, zooecia polygonal, commonly 5- or 6-sided, rarely subround, with thin amalgamate walls; generally (12 of 20 measurements) five entire zooecia and part of sixth in 2 mm.; somewhat less commonly (8 of 20 measurements) four entire zooecia and portion of fifth in this distance; zooecia relatively uniform in size, except for a few conspicuously smaller young zooecia that typically are subpolygonal. Acanthopores small- to medium-sized, noninflecting or slightly inflecting, and generally situated at junction points of adjoining zooecia; typically two to four acanthopores associated with each zooecium. Clusters of somewhat larger zooecia may represent maculae. Mesopores lacking.

In longitudinal section of hemispherical zoarium, zooecia radiate outward and upward from center of base; in encrusting zoarium, zooecia erect throughout. Zooecial walls of essentially uniform thickness throughout zoarium, possibly somewhat thicker in outer part of colony, and showing laminae obscurely; locally wall integrate, revealing poorly defined black divisional line. Diaphragms absent or rare, usually not more than four or five per zooecium. Acanthopores locally discernible; mesopores lacking.

Remarks.—Characteristic features of this species are the absence or small number of diaphragms and the comparatively large zooecia; most species of *Cyphotrypa* Ulrich & Bassler have six or seven, or more, zooecia in 2 mm. Many zooecia in the holotype lack diaphragms; in one of the paratypes, dia phragms are generally more common in the basal one-third of the zoarium where they are two or three zooecial diameters apart and tend to be developed at approximately similar levels across the zoarium.

This species can be distinguished readily from late Ordovician and younger species of *Cyphotrypa*. *C. osgoodensis* differs from *C. corrugata* (Weller) of Helderbergian (early Devonian) age in having larger zooecia, fewer diaphragms, in lacking crenulated walls, and in having more prominently developed acanthopores; from *C. polygona* Bassler of the Ellis Bay Formation (Gamachian) in its more conspicuous acanthopores, distinctly fewer diaphragms, and somewhat larger zooecia; and from *C. expanda* Bassler of the Tonoloway Formation (Cayugan) in having more prominent acanthopores, larger zooecia, and fewer diaphragms. The closest relative to *C. osgoodensis* is *C. bulbosa* (Billings) from the Ellis Bay Formation of Anticosti Island from

which it differs mainly in having larger zooecia. Resemblances between these two species include similar prominence and numbers of acanthopores, small number of diaphragms, and a not entirely dissimilar zoarial form.

Genus STIGMATELLA Ulrich & Bassler, 1904
STIGMATELLA DUBIA Perry & Hattin, n. sp.
Pl. 88, figs. 2,5–7

External description.—Zoarium ramose, somewhat compressed, the fragments as much as 32 mm. long and 11 mm. in maximum diameter; zoarial surface weathered and not revealing monticules or maculae.

Internal description.—In tangential section, zooecia subround or subpolygonal and having thick (0.02 to 0.05 mm.) homogeneously fibrous amalgamate walls; typically (21 of 30 measurements) six entire zooecia and portion of seventh in 2 mm., measuring parallel to length of zoarium; commonly (7 of 30 measurements) seven complete zooecia and part of eighth in this distance; and rarely (2 of 30 measurements) five entire zooecia and portion of sixth in 2 mm. Acanthopores large (commonly 0.04 to 0.06 mm. in diameter) and having thick dark concentrically fibrous walls enclosing a minute central tubule; typically four to seven acanthopores associated with ten zooecia. Mesopores common, irregularly polygonal, and usually less than one-third the size of a zooecium; some structures simulating mesopores most probably small young zooecia. Neither monticules nor maculae definitely recognizable, presumably poorly developed or lacking.

In longitudinal section, zooecia erect in axial region, bending gradually to surface which they meet perpendicularly; zooecial walls locally crenulated, thickening gradually toward zoarial surface, and consisting of laminae broadly convex outward. Diaphragms in axis typically one and one-half to three zooecial diameters apart, in mature region usually less than one zooecial diameter apart. Two clearly defined zones in axis and submature region marked by more closely spaced diaphragms; thickening of zooecial walls, presumably indicative of periodic development of acanthopores, closely associated with zones of closely spaced diaphragms. Mesopores tabulate, moniliform, confined largely to mature region, and locally pinching out below zoarial surface.

Remarks.—This species can be identified readily by its large well defined acanthopores. Diaphragms are more abundant than in most members of this genus.

This species is assigned to *Stigmatella* with some hesitancy. Most species of *Stigmatella* have smaller acanthopores than those in *S. dubia;* acanthopores in *S. nickelsi* Ulrich & Bassler, however, are comparable in size with those of *S. dubia.* Further, most *Stigmatella* species have fewer diaphragms than *S. dubia.* Structural features suggesting assignment to *Stigmatella* are: (1) zooecial walls are locally crenulated, (2) mesopores tend to be moniliform, and (3) periodic thickenings of zooecial wall during development of zoarium.

Stigmatella, a common Ordovician genus, is found rarely in rocks of Silurian age. *S. globata* Bassler from the Rochester Shale (Niagaran) differs from *S. dubia* in having fewer diaphragms, less prominent acanthopores, and in the form of the zoarium.

The specific name reflects some hesitancy in assigning this species to *Stigmatella.*

Family CONSTELLARIIDAE Ulrich, 1890
Genus HENNIGOPORA Bassler, 1952
HENNIGOPORA APTA Perry & Hattin, n. sp.
Pl. 88, figs. 1,3,4

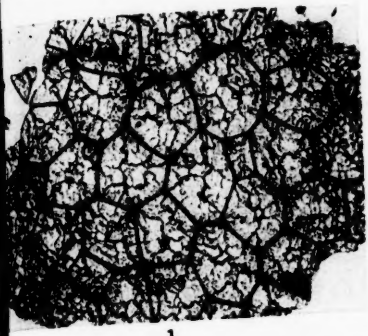
External description.—Zoarium encrusting, encircling a crinoid stem; length of zoar-

---

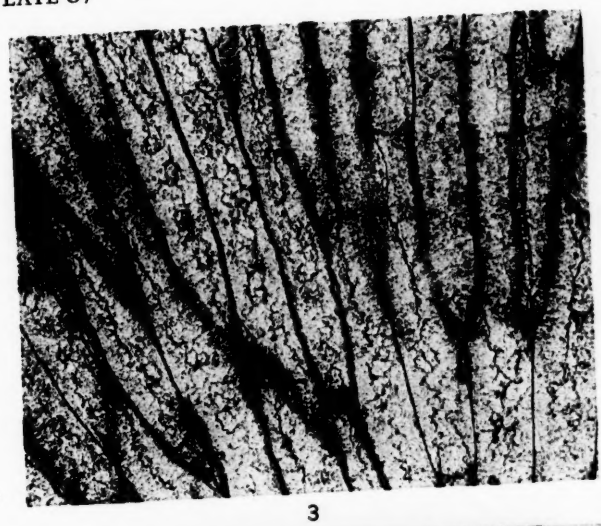
EXPLANATION OF PLATE 87

FIGS. *1–3—Cyphotrypa osgoodensis* Perry & Hattin, n. sp. Holotype (Indiana Univ. Paleont. Coll. 5568) from Osgood Formation, Osgood Indiana. *1,* Tangential section, ×20; *2,* tangential section, ×60; and *3,* longitudinal section, ×20.

4–6—Heterotrypa? perplexa Perry & Hattin, n. sp. Holotype (Indiana Univ. Paleont. Coll. 5567) from Osgood Formation, Osgood, Indiana. *4,* Longitudinal section showing line of rejuvenation, ×20; *5,* tangential section, ×20; and *6,* tangential section showing numerous, locally somewhat inflecting acanthopores and several mesopores, ×60.

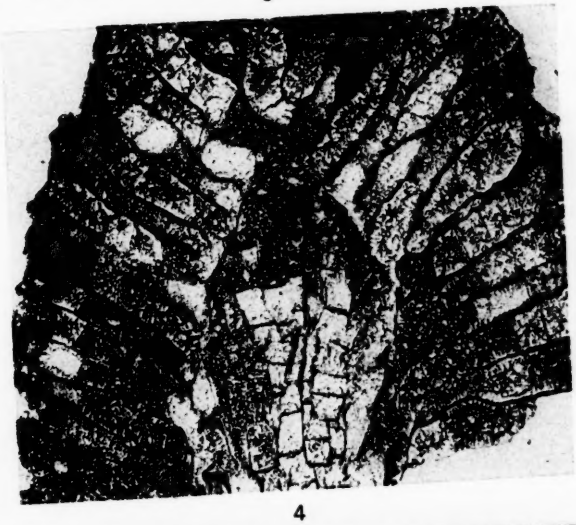


1



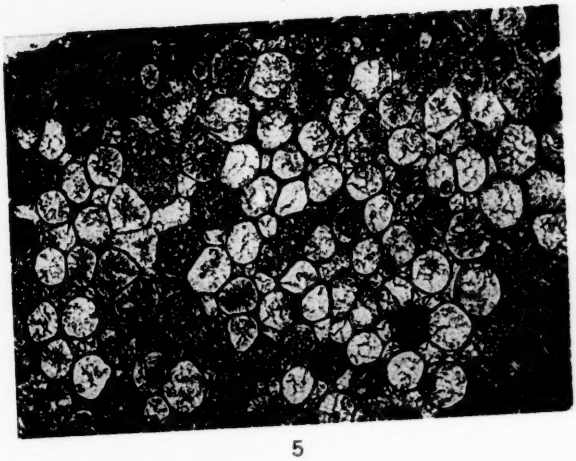
3

2



4

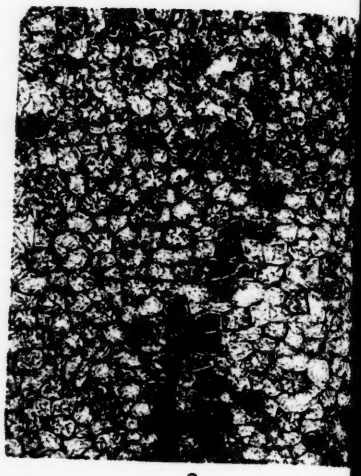
6



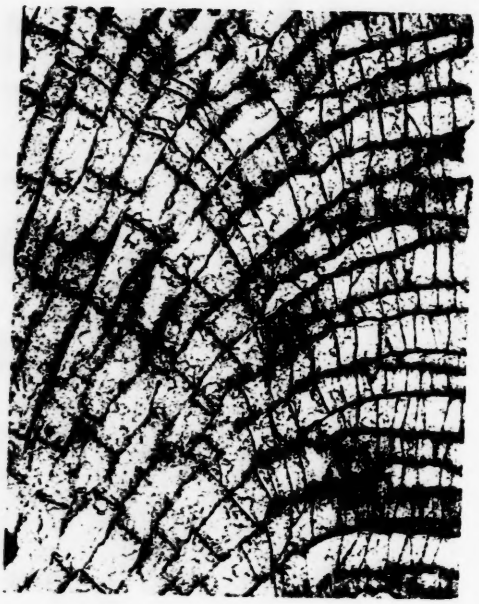
5

1

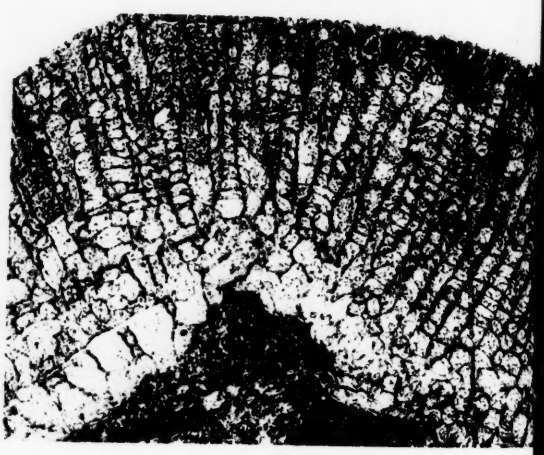
2



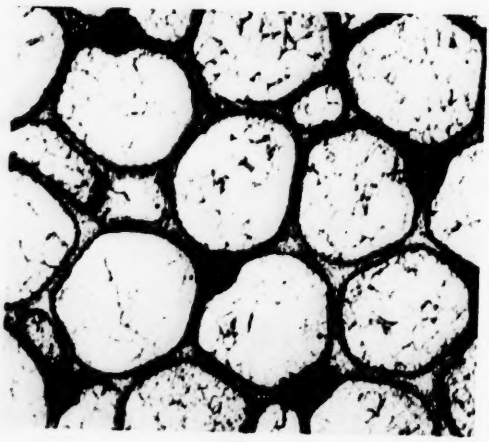
3



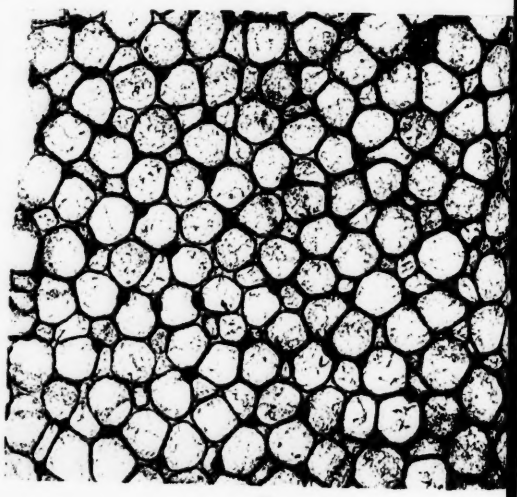
5



4



6



7

ium 20 mm., maximum observed thickness of zoarial growth 4.1 mm. Zooecial apertures petaloid because zooecial walls inflected by many acanthopores. Monticules sparse, low, inconspicuous, and flanked by radially aligned zooecia.

Internal description.—In tangential section, zooecia petaloid, subround to broadly ovate in gross outline, and having thin fibrous amalgamate walls; most commonly (8 of 15 measurements) six entire zooecia and part of seventh in 2 mm.; commonly (5 of 15 measurements) seven complete zooecia and part of eighth in this distance; rarely (2 of 15 measurements) six entire zooecia in 2 mm.; average maximum zooecial diameter (based on 15 measurements) 0.20 mm., ranging from 0.16 to 0.22 mm. Acanthopores small, commonly indenting zooecial cavity, and consisting of an outer band of concentrically arranged light-colored fibers embracing the darker-colored acanthopore center composed of concentric fibers; typically three to five acanthopores per zooecium. Interzooecial vesicles polygonal or subangular, generally ranging from one-third the size of a zooecium to somewhat larger than a zooecium; typically one vesicle between adjacent zooecia; average interzooecial distance (based on 15 measurements) 0.14 mm., ranging from 0.06 to 0.26 mm.

In longitudinal section, zooecia erect, containing sparse irregularly spaced diaphragms in outer half of zoarium but with these structures usually spaced from one to two zooecial diameters apart in lower portion of zoarium; zooecial wall consisting of fibers which are continuous into diaphragms. Acanthopores prominent, commonly observable for a distance of several zooecial diameters, and forming light-colored passageways in the zooecial walls. Vesicles coarse, highly convex outward, and irregularly arranged at base of outer layer of zoarial growth; elsewhere, vesicles crudely rectangular and locally in interlocking columns.

Remarks.—This species differs sharply from *Hennigopora florida* (Hall) in (1) possessing more zooecia in 2 mm., (2) lacking or nearly lacking diaphragms in the mature or outer part of the zoarium, and (3) having fewer acanthopores per zooecium. The authors believe that *Nicholsonella ringuebergi* Bassler should be included in the recently established genus *Hennigopora*. *H. apta* resembles *H. ringuebergi* in the number of zooecia in 2 mm., diameter of the zooecia, and possibly mode of growth; these two species differ, however, as *H. ringuebergi* lacks diaphragms.

The specific name *apta* (meaning suitable or appropriate) was selected because this species fulfills all requirements for inclusion in *Hennigopora*, *viz.* numerous acanthopores indenting the zooecia and interzooecial areas occupied by polygonal vesicles.

Family HALLOPORIDAE Bassler, 1911

Genus HALLOPORA Bassler, 1911

HALLOPORA ELEGANTULA (Hall), 1852

Pl. 89, figs. 4,5

Callopora elegantula HALL, 1852, Paleontology New York, v. 2, p. 144, pl. 40, figs. 1a–n; 1882, Ann. Rept. Indiana Dept. Geol. and Nat. Hist., p. 237, 238; ULRICH, 1882, Jour. Cincinnati Soc. Nat. Hist., v. 5, p. 250, pl. 11, figs. 6–6b; ZITTEL, 1896, Text-Book of Paleontology (Eng. Ed.), p. 274, figs. 465A,B; SIMPSON, 1897, 14th Ann. State Geol. New York 1894, pl. 18, figs. 1–7; GRABAU, 1901, New York State Mus., Bull. 45, p. 167, fig. 67; GRABAU, 1901, Buffalo Soc. Nat. Sci., Bull. 7, p. 167, fig. 67; BASSLER, 1906, U. S. Geol. Survey, Bull. 292, p. 41, pl. 17, figs. 11–15, pl. 26, fig. 12; GRABAU &

EXPLANATION OF PLATE 88

FIGS. *1,3,4*—*Hennigopora apta* Perry & Hattin, n. sp. Holotype (Indiana Univ. Paleont. Coll. 5572) from Osgood Formation, Osgood, Indiana. *1*, Tangential section showing inflection of zooecial walls by acanthopores, ×60; *3*, tangential section, ×20; and *4*, longitudinal section showing acanthopores, ×20.

2,5–7—*Stigmatella dubia* Perry & Hattin, n. sp. Holotype (Indiana Univ. Paleont. Coll. 5570) from Osgood Formation, Osgood, Indiana. *2*, Longitudinal section showing zones marked by closely spaced diaphragms and periodic development of acanthopores, ×4; *5*, longitudinal section, ×20; *6*, tangential section showing central tubules in acanthopores, ×60; and *7*, tangential section, ×20.

SHIMER, 1907, North American Index Fossils, v. 1, p. 140, figs. 195a,b.

Callopora nana NICHOLSON, 1884, Ann. Mag. Nat. Hist., 5th ser., v. 13, p. 120, pl. 7, figs. 4–4b.

Hallopora elegantula (HALL), BASSLER, 1911, U. S. Nat. Mus., Bull. 77, p. 334, 335, fig. 210; ZITTEL-EASTMAN, 1913, Textbook of Paleontology, v. 1, p. 337, figs. 491A,B; BASSLER *in* TWENHOFEL, 1928, Canadian Geol. Survey, Mem. 154, p. 153; SHIMER & SHROCK, 1944, Index Fossils of North America, p. 261, pl. 99, figs. 6,7; MOORE *et al.*, 1952, Invertebrate Fossils, p. 167, figs. 5–6,10a,b; BASSLER, 1953, Treat. Invertebrate Paleontology, pt. G., Bryozoa, p. G112, fig. 74, 1a–e.

External description.—Zoarium ramose, dichotomously branched, ovate in cross section, and ranging from 2 to 5 mm. in larger diameter; largest specimen 19.3 mm. long. Surface smooth, lacking monticules, but showing maculae composed of angular mesopores.

Internal description.—In tangential section, zooecia circular or broadly ovate; average maximum zooecial diameter (based on 50 measurements) 0.39 mm., ranging from 0.34 to 0.46 mm.; typically (23 of 35 measurements) four entire zooecia or four complete zooecia and portion of fifth in 2 mm., measuring parallel to length of zoarium; commonly (9 of 35 measurements) three entire zooecia and portion of fourth in this distance; rarely (2 of 35 measurements) five complete zooecia or (1 of 35 measurements) three entire zooecia in 2 mm.; zooecial walls generally about 0.03 mm. thick, consisting of finely laminated tissue, the laminae parallel to zooecial walls and commonly showing spurlike projections of zooecial wall material extending a short distance into zooecia. Mesopores variable in shape, usually one-fifth to nearly one-half the size of a zooecium, and generally one or two partially separating adjacent zooecia. Maculae consisting of angular to subangular mesopores. Acanthopores lacking.

In longitudinal section, zooecia erect, thin-walled in axis, curving gradually to meet zoarial surface at right angles. Zooecial walls in peripheral region consisting of fine laminae moderately convex outward; laminae in outer part of zooecial wall clearly continuous into thin laminated diaphragms; zooecial wall microstructure not clearly discernible in axial region. Diaphragms variably spaced but having tendency to show following distribution: in central axis, diaphragms generally slightly more than one zooecial diameter apart, somewhat more closely spaced in outer part of axial region, about one to one and one-half zooecial diameters apart at base of mature or peripheral zone, and usually one-half zooecial diameter apart in outer mature region. Mesopores confined to peripheral region, closely tabulate, and apparently subdividing locally near zoarial surface.

Remarks.—Although mesopores are common, they generally do not completely isolate neighbouring zooecia whose walls are commonly in local contact. Longitudinal sections show that zooecial wall thickness increases gradually from the axis to the zoarial surface.

Family TREMATOPORIDAE Miller, 1889

Genus TREMATOPORA Hall, 1851

TREMATOPORA sp.

Pl. 89, figs. 1–3

External description.—Zoarium a sheetlike growth, less than 2 mm. thick and encrusting a crinoid stem 19 mm. long. Mesopores round, abundant; neither monticules nor maculae observed.

Internal description.—In tangential section, thick-walled zooecia subround to round, rarely subangular, and partially in contact; zooecial walls commonly but not invariably integrate. Average maximum diameter (based on 20 measurements) of zooecial aperture, not including zooecial walls, 0.25 mm., ranging from 0.21 to 0.28 mm. Typically (11 of 20 measurements) five entire zooecia and part of sixth in 2 mm.; less commonly (5 of 20 measurements) six complete zooecia and part of seventh or (4 of 20 measurements) five entire zooecia in 2 mm. Mesopores round, subangular, or crudely rectangular, ranging in size from about one-tenth to somewhat over one-half the size of a typical zooecium, and so abundant that adjacent zooecia are only in partial contact. Acanthopores questionably present. Conclusive evidence of either monticules or maculae lacking.

In longitudinal section, zooecia somewhat recumbent near base, later erect, and generally thick-walled throughout length; zooecial walls integrate, showing a somewhat crinkled well defined dark-colored divisional

line and consisting of fibers acutely convex outward. Diaphragms commonly lacking, not more than two per zooecium, and consisting of extensions of fibrous material of zooecial walls. Mesopores few, moniliform, and sparsely tabulate. Acanthopores not observed.

Remarks.—The single specimen is considered the basal expansion of a ramose species because a protuberance from the zoarial surface undoubtedly represents incipient branching. A specific name is not assigned as the early formed basal expansion most probably differs structurally from the adult zoarium.

Acanthopores cannot be identified with certainty. The tangential section commonly displays black dots composed of concentrically arranged fibers highly suggestive of acanthopores or finely granular material. As these dotlike structures are not distributed throughout the zoarium but are confined to restricted areas, they may represent locally developed coarse granules in the zooecial walls. Four longitudinal sections do not display any evidence of acanthopores.

Moniliform or beadlike mesopores strongly suggested assignment of the specimen to *Trematopora* Hall as did the rounded thick-walled zooecia and the very sparse development of diaphragms. Consideration was also given to including the specimen in *Eridotrypa* Ulrich because the tangential section of this specimen bears some resemblance to that of the Middle Silurian species *Eridotrypa similis* Bassler.

Genus DIPLOTRYPA Nicholson, 1879
DIPLOTRYPA NUMMIFORMIS (Hall), 1852
Pl. 89, figs. 6,7

Callopora nummiformis HALL, 1852, Paleontology New York, v. 2, p. 148, pl. 40, figs. 5a,b.
Diplotrypa milleri ULRICH, 1882, Jour. Cincinnati Soc. Nat. Hist., v. 5, p. 245–247, pl. 11, figs. 2–2c.
Mesotrypa nummiformis (HALL), BASSLER, 1906, U. S. Geol. Survey, Bull. 292, p. 27, pl. 10, figs. 1–4.

External description.—Zoarium discoidal, upper surface very gently convex, lower surface flat or very gently concave; width of zoarium about 14 mm., maximum thickness 2 mm. Maculae inconspicuous, about 3 or 4 mm. apart measuring from center to center, and composed of mesopores and generally about five or six zooecia, the latter somewhat above average size.

Internal description.—In tangential section, zooecia thin-walled, subround or subpolygonal; typically six zooecia and portion of seventh or seven entire zooecia in 2 mm.; rarely six complete zooecia or seven entire zooecia and part of eighth in this distance. Adjacent zooecia largely separated by mesopores but in contact locally. Zooecia in maculae slightly above average size. Mesopores abundant, generally subtriangular to crudely rectangular and characteristically ranging in size from one-quarter to somewhat over one-half the size of a zooecium. Acanthopores lacking.

In longitudinal section, zooecia erect, walls not thickening appreciably from base to surface of zoarium. Diaphragms horizontal or somewhat oblique in zooecia and usually less than one zooecial diameter apart; in mesopores, diaphragms horizontal, conspicuously more closely and more regularly spaced than in zooecia. Mesopores continuous throughout zoarium. Acanthopores lacking.

Remarks.—This species is represented by five specimens in our collections. Species of *Diplotrypa* Nicholson, *Mesotrypa* Ulrich, and *Monotrypa* Nicholson commonly display the same zoarial form. *Diplotrypa* can be recognized readily from *Monotrypa* as the latter genus lacks mesopores and from *Mesotrypa* which has acanthopores as well as mesopores.

Genus MONOTRYPA Nicholson, 1879
MONOTRYPA OSGOODENSIS Bassler, 1906
Pl. 90, figs. 1,2

Monotrypa osgoodensis BASSLER, 1906, U. S. Geol. Survey, Bull. 292, p. 46, pl. 16, figs. 1–5.

External description.—Zoarium hemispherical, upper surface convex, base flat or slightly concave and concentrically wrinkled; diameter of base ranging from 5 to 20 mm., and height ranging from 3 to 12 mm.; zoarial surface smooth and showing irregularly distributed maculae consisting of somewhat larger zooecia.

Internal description.—In tangential section, zooecia generally five- or six-sided, nearly angular to subround; zooecial walls amalgamate, very rarely integrate, finely laminated, commonly 0.01 to 0.02 mm.

thick; typically (66 of 100 measurements) four entire zooecia and part of fifth in 2 mm.; commonly (31 of 100 measurements) five complete zooecia and portion of sixth in this distance; and rarely (3 of 100 measurements) three entire zooecia and part of fourth in 2 mm. Maculae irregularly spaced, not well defined, and consisting of four to six zooecia approximately one-quarter larger than zooecia of intermacular areas. Mesopores and acanthopores lacking.

In longitudinal section, zooecia extend upward and outward from center of base of zoarium. Diaphragms thin, usually from one-half to five zooecial diameters apart, somewhat more closely spaced in outer part of zoarium; rarely and locally poorly defined zones of closely spaced diaphragms. Zooecial wall material consisting of fine laminae moderately to broadly convex outward; outer laminae of wall continuous into diaphragms.

Remarks.—In most specimens the regularly arranged zooecia are comparatively uniform in size. Some specimens, however, display a small subangular to ovate zooecium in association with every 12 to 30 normal-sized zooecia. Mature and immature zones are very poorly defined because zooecial walls do not thicken appreciably from the base to the upper surface of the zoarium and diaphragm spacing does not change materially throughout the thickness of the zoarium.

MONOTRYPA BENJAMINI Bassler, 1906
Pl. 90, figs. 3,4

Monotrypa benjamini BASSLER, 1906, U. S. Geol. Survey, Bull. 292, p. 46, 47, pl. 16, figs. 6–9, pl. 26, fig. 11.

External description.—Zoarium subglobular, increasing in diameter upward from subplanar base; maximum diameter 19 mm., maximum height 9 mm.; surface smooth, weathered, locally displaying sharp angular zooecia but not showing monticules or maculae.

Internal description.—In tangential section, zooecia sharply angular or subangular, commonly four- to six-sided, and showing considerable variation in size; most commonly (13 of 20 measurements) four entire zooecia and part of fifth in 2 mm.; less commonly (4 of 20 measurements) five complete zooecia and portion of sixth or (3 of 20 measurements) three entire zooecia and part of fourth in 2 mm. Zooecial walls commonly having thin irregularly and minutely fibrous dark line bounded on either side by distinct granular material differing markedly in appearance from crystalline calcite in zooecia. Mesopores and acanthopores lacking.

In longitudinal section, zooecia emanate upward and outward from center of base of zoarium. Zooecial walls of uniform thickness throughout zoarium, not revealing microstructure, and generally showing 12 to 22 sharply defined crenulations in 2 mm. measured along zooecial wall in upper half of zoarium; zooecial walls in lower part of zoarium generally not crenulated but mildly flexuous. Diaphragms lacking.

Remarks.—The distinguishing features of this species are the strikingly crenulated zooecial walls and the absence of diaphragms. In tangential section, the zooecia show more variation in size than those of *Monotrypa osgoodensis* Bassler.

MONOTRYPA EXSERTA Perry & Hattin, n. sp.
Pl. 90, figs. 7–9

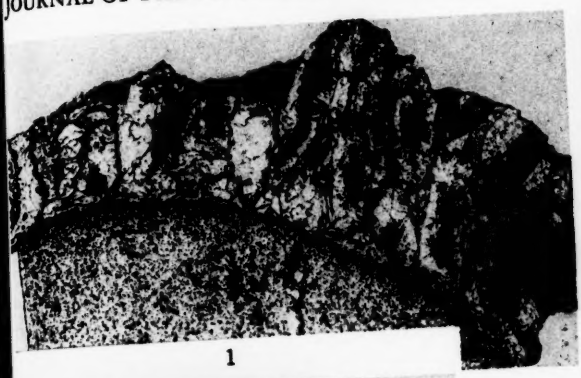
External description.—Zoarium discoidal, upper surface mildly convex, base shallowly concave; maximum diameter 20 mm., maxi-

EXPLANATION OF PLATE 89

FIGS. *1–3*—*Trematopora* sp. Described specimen (Indiana Univ. Paleont. Coll. 5574) from Osgood Formation, Osgood, Indiana. *1*, Longitudinal section, ×20; 2, tangential section, ×60; and *3*, tangential section, ×20.

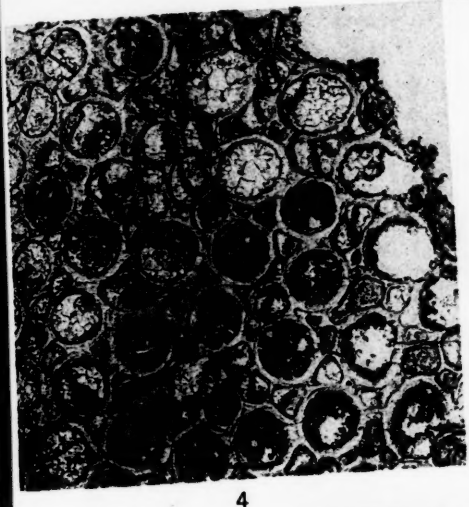
4,5—*Hallopora elegantula* (Hall). Hypotype (Indiana Univ. Paleont. Coll. 5573) from Osgood Formation, Osgood, Indiana, each ×20. *4*, Tangential section showing spurlike projections of zooecial wall material into zooecia; and *5*, longitudinal section.

6,7—*Diplotrypa nummiformis* (Hall). Hypotype (Indiana Univ. Paleont. Coll. 5575) from Osgood Formation, Osgood, Indiana, each ×20. *6*, Longitudinal section; and *7*, tangential section.

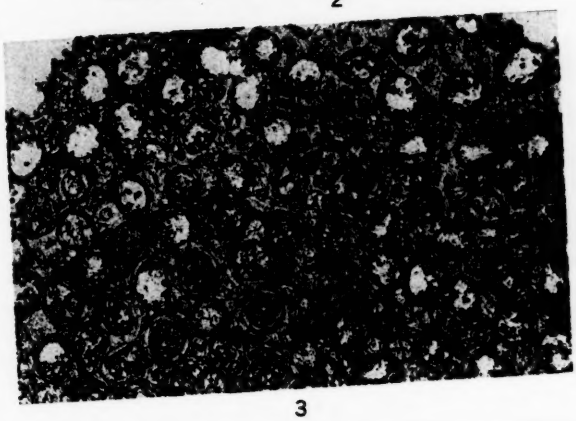


1

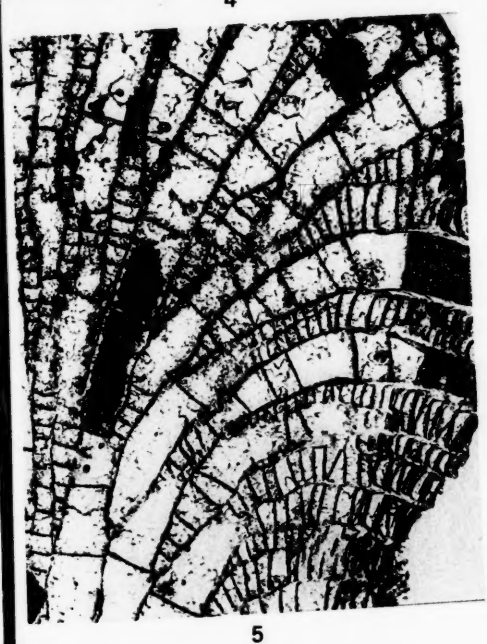
2



4

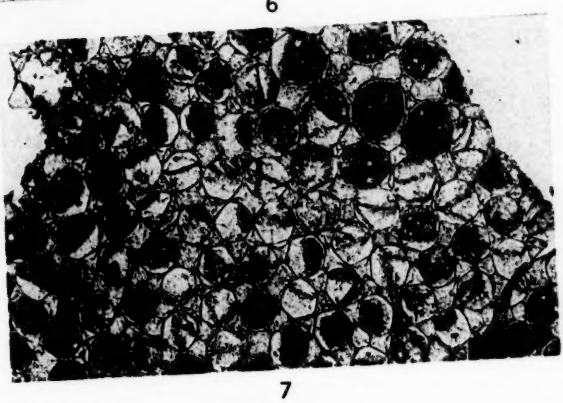


3

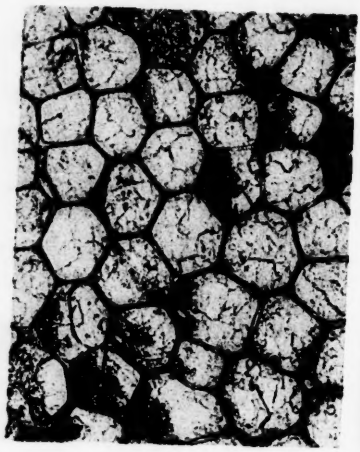


5

6



7

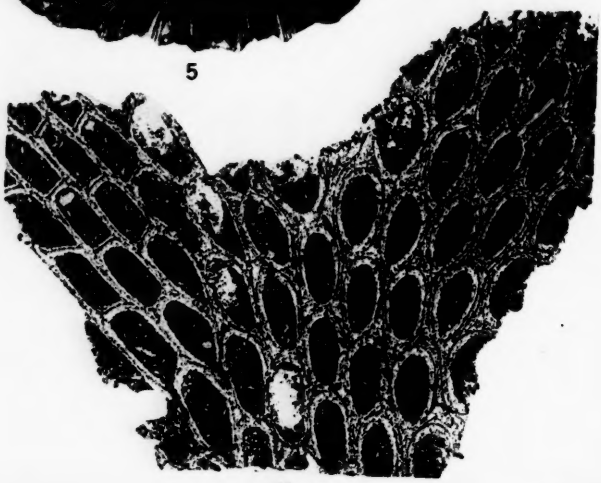


1

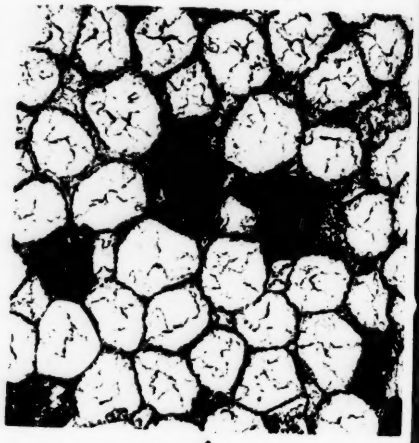
2

3

5



6



4

7

8

9

mum thickness 3.2 mm.; thickness of zoarium greatest at center of colony, decreasing toward periphery. Zoarial surface smooth, displaying irregularly sized and shaped zooecia but not showing maculae or monticules.

Internal description.—In tangential section, zooecia angular to nearly round, most commonly subangular, and highly variable in size; typically seven to nine entire zooecia in 2 mm. Zooecial walls generally 0.01 to 0.02 mm. thick, usually integrate, containing a central dark line, composed of tangled fibers, and bordered by more transparent tissue formed of fine laminae parallel to wall margins; locally but commonly zooecial walls amalgamate; spurlike projections of wall material into zooecia common. Mesopores and acanthopores absent.

In longitudinal section, zooecia partially recumbent in early growth stages, later erect, and emanating upward and outward from initial growth area in center of base of zoarium. Zooecial walls of uniform thickness throughout zoarium and commonly displaying a central finely fibrous dark line flanked on both sides by more transparent laminated material that is continuous into diaphragms. Initial growth stages of overlapping cystlike structures. Diaphragms thin, usually one-half to two and one-half zooecial diameters apart, and irregularly spaced throughout zoarium.

Remarks.—The characteristic features of *Monotrypa exserta* are the spurlike projections of zooecial wall material into the zooecia and the irregularity in size and shape of the zooecia as observed in tangential section. Because of the conspicuous variation in the size of the zooecia, their number in a 2-mm. distance is not as regular as in many bryozoan species. *M. exserta* differs from *M. osgoodensis* Bassler, its closest relative in this faunule, in having much greater irregularity in the size and shape of the zooecia and in having spurlike projections of zooecial wall material projecting into the zooecia; the latter character suggested the specific name.

The paratype displays thicker walls and less well defined zooecial walls in tangential section than does the holotype. This is considered a surficial preservation feature because, a short distance below the surface, zooecial walls in the paratype are of normal thickness.

Order CRYPTOSTOMATA
Family RHINIDICTYIDAE Ulrich, 1895
Genus PACHYDICTYA Ulrich, 1882
PACHYDICTYA CRASSA (Hall), 1852
Pl. 90, figs. 5,6

Stictopora crassa HALL, Paleontology New York, v. 2, p. 45, pl. 18, figs. 4a–c.
Stictopora scitula HALL & SIMPSON, 1887, Paleontology New York, v. 6, pl. 61, figs. 24,25.
Ptilodictya farctus FOERSTE, 1889, Proc. Boston Soc. Nat. Hist., v. 24, p. 328, pl. 6, fig. 31.
Ptilodictya rudis FOERSTE, 1889, Proc. Boston Soc. Nat. Hist., v. 24, p. 329, pl. 6, fig. 33.
Pachydictya crassa (HALL), ULRICH, 1893, Geol. Minnesota, v. 3, p. 147; BASSLER, 1906, U. S. Geol. Survey, Bull. 292, p. 57, pl. 18, figs. 11, 12, pl. 21, figs. 14–16; BASSLER *in* TWENHOFEL, 1928, Canadian Geol. Survey, Mem. 154, p. 167; SHIMER & SHROCK, 1944, Index Fossils of North America, p. 270, pl. 102, fig. 5.
Pachydictya farctus FOERSTE, 1895, Geol. Survey Ohio, v. 7, p. 599, pl. 31, fig. 31.
Pachydictya rudis FOERSTE, 1895, Geol. Survey Ohio, v. 7, p. 599, pl. 31, figs. 32,33.

EXPLANATION OF PLATE 90

FIGS. *1,2*—*Monotrypa osgoodensis* Bassler. Hypotype (Indiana Univ. Paleont. Coll. 5576) from Osgood Formation, Osgood, Indiana, each ×20. *1*, Tangential section; and *2*, longitudinal section.
3,4—*Monotrypa benjamini* Bassler. Hypotype (Indiana Univ. Paleont. Coll. 5577) from Osgood Formation, Osgood, Indiana, each ×20. *3*, Longitudinal section; and *4*, tangential section.
5,6—*Pachydictya crassa* (Hall). Hypotypes (Indiana Univ. Paleont. Coll. 5578) from Osgood Formation, Osgood, Indiana, each ×20. *5*, Transverse section showing row of median tubules; and *6*, tangential section.
7–9—*Monotrypa exserta* Perry & Hattin, n. sp. Holotype (Indiana Univ. Paleont. Coll. 5580) from Osgood Formation, Osgood, Indiana. *7*, Longitudinal section, ×20; *8*, tangential section showing spurlike projections of zooecial wall material into zooecia, ×60; and *9*, tangential section, ×20.

External description.—Zoarium ramose, dichotomously branched, erect, bifoliate. Branches with sharp parallel edges, more than twice as broad as thick, ranging from 1.7 to 3.0 mm. in width and from 0.5 to 1.2 mm. in thickness. Long dimensions of branches oriented more or less in one plane. Apertures oval, elongated in parallel longitudinal rows separated by very low continuous ridges, and with low thick peristomes that are inconspicuous in most specimens. Outer margins of branches noncelluliferous in largest specimen. For 20 measurements, three and one-half to four zooecia in 2 mm.

Internal description.—In tangential section, zooecia range from 0.39 to 0.50 mm. in maximum diameter, averaging 0.44 mm. for 20 measurements. Zooecial walls range from 0.06 to 0.17 mm., averaging 0.10 mm. for 20 measurements.

In transverse section, branches narrowly elliptical. Zooecia short nontabulated tubes. Bifoliate structure emphasized by distinct mesotheca containing a row of tiny median tubules. Walls thin at base of zooecia, expanding greatly toward mature region.

In longitudinal section, zooecia of immature region directed obliquely outward but turning gradually to intersect zoarial surface nearly at right angles in mature region. Zooecial walls of nearly uniform thickness. Mesotheca prominently displayed. Diaphragms and hemisepta lacking.

Remarks.—None of our specimens reveals the faint striae along the branch margins that have been reported previously.

REFERENCES

BASSLER, R. S., 1906, The bryozoan fauna of the Rochester shale: U. S. Geol. Survey, Bull. 292, 137 p., 31 pls.

——, 1915, Bibliographic index of American Ordovician and Silurian fossils: U. S. Nat. Mus., Bull. 92, v. 2, p. 719–1521, 4 pls.

BOYCE, M. W., 1956, The macropaleontology of the Osgood Formation (Niagaran) in Ripley County, Indiana: Unpub. Master's thesis, Indiana Univ.

BUTTS, CHARLES, 1915, Geology and mineral resources of Jefferson County, Kentucky: Kentucky Geol. Survey, ser. 4, v. 3, pt. 2, p. 1–270, 65 pls.

CUMINGS, E. R., 1922, Nomenclature and description of the geological formations of Indiana, *in* Handbook of Indiana Geology: Indiana Dept. Conserv., Pub. 21, pt. 4, p. 403–570, 31 figs.

DUNN, P. H., 1942, Silurian Foraminifera of the Mississippi basin: Jour. Paleontology, v. 16, p. 317–342, 3 pls.

FOERSTE, A. F., 1896, An account of the middle Silurian rocks of Ohio and Indiana: Cincinnati Soc. Nat. Hist. Jour., v. 18, p. 161–200, 1 pl.

——, 1897, Geology of the middle and upper Silurian rocks of Clark, Jefferson, Ripley, Jennings, and southern Decatur Counties, Indiana: Indiana Dept. Geol. & Nat. Resources, 21st Ann. Rept., p. 213–288, 4 pls.

——, 1898, A report on the Niagaran limestone quarries of Decatur, Franklin, and Fayette Counties, with remarks on the geology of the middle and upper Silurian rocks of these and neighbouring (Ripley, Jennings, Bartholomew, and Shelby) Counties: Indiana Dept. Geol. & Nat. Resources, 22nd Ann. Rept., p. 195–255, 5 pls.

——, 1904, Description of the rocks formed in the different geological periods of Indiana; Ordovician and Silurian: Indiana Dept. Geol. & Nat. Resources, 28th Ann. Rept., p. 21–39.

——, 1931, The Silurian fauna of Kentucky, *in* The paleontology of Kentucky: Kentucky Geol. Survey, ser. 6, v. 36, p. 1–469, 80 pls.

——, 1935, Correlation of Silurian formations in southwestern Ohio, southeastern Indiana, Kentucky, and western Tennessee: Denison Univ. Bull., Sci. Lab. Jour., v. 30, art. 3, p. 119–205.

HALL, JAMES, 1882, Descriptions of the species of fossils found in the Niagara group at Waldron, Indiana: Indiana Dept. Geol. & Nat. Resources, 11th Ann. Rept., p. 217–345, 36 pls.

MCFARLAN, A. C., 1943, Geology of Kentucky: Univ. Kentucky, Lexington, Ky., 531 p., 117 pls.

PERRY, T. G. & HATTIN, D. E., 1955, Osgood (Niagaran) bryozoans from the type area: Geol. Soc. America, Bull., v. 66, no. 12, p. 1695, 1696. (Abs.)

RAYMOND, P. C., 1955, Arenaceous Foraminifera from the Osgood (middle Silurian) formation, Indiana: Unpub. Master's thesis, Indiana Univ.

STOUT, WILBER, 1941, Dolomites and limestones of western Ohio: Ohio Geol. Survey, Fourth Ser., Bull. 42, p. 1–468.

STEWART, G. A. & PRIDDY, R. R., 1941, Arenaceous Foraminifera from the Niagaran rocks of Ohio and Indiana: Jour. Paleontology, v. 15, p. 366–375, 1 pl.

SWARTZ, C. K., and others, 1942, Correlation of the Silurian formations of North America: Geol. Soc. America, Bull., v. 53, p. 533–538, 1 pl.

WILSON, C. W., JR., 1949, Pre-Chattanooga stratigraphy in central Tennessee: Tennessee Dept. Conserv., Div. Geol., Bull. 56, p. 1–407, 28 pls.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 711–716, PL. 91, JULY, 1960

FAUNA FROM THE TENSLEEP SANDSTONE IN WYOMING

R. D. HOARE AND J. D. BURGESS
Bowling Green State University, Bowling Green, Ohio, and
The Carter Oil Company, Riverton, Wyoming

ABSTRACT—New collections from the Tensleep sandstone in the Wind River Basin and Big Horn Basin of Wyoming contain nine species of brachiopods, one scaphopod, one gastropod, and one trilobite. All specimens are either referable to previously described species or are impossible to identify specifically. This fauna strengthens the conclusion that the Tensleep sandstone in this region is Desmoinesian in age.

INTRODUCTION

FOSSILS are relatively rare in the Tensleep sandstone in Wyoming. During 1958 the junior author discovered a fossiliferous locality in the Little Warm Springs Creek area associated with chert nodules in the lower portion of the Tensleep sandstone. Later he obtained a collection from near the top of the Tensleep sandstone in the Big Horn Basin.

The Tensleep sandstone was named by Darton in 1904. Branson (1939) grouped the Tensleep sandstone and the Amsden formation under the name Tensleep, although he recognized that the lower portion of this sequence is Mississippian in age and the upper portion is Pennsylvanian in age. In that portion of the sequence which is now recognized as the Tensleep sandstone, Branson collected a number of specimens from several different localities which indicate a Desmoinesian age. As far as is known, none of these fossils has been reported previously from these two localities nor have any of them been figured from this general area, except for the general photographs by Brainerd & Keyte (1927).

Thomas (1948) placed the Tensleep sandstone in the Pennsylvanian on the basis of fusilinids. On a correlation chart in the 1957 Wyoming Geological Association Guidebook, Agatston indicates the presence of fusilinids ranging in age from Lower Desmoinesian to Missourian in the Tensleep sandstone. Keefer (1957) places the Tensleep sandstone in the Pennsylvanian and mentions the occurrence of fossil fragments in the lower one foot of the formation at a Little Warm Springs Creek locality.

M. L. Thompson (personal communication) reports that the fauna from the Shell Canyon locality contains specimens of *Fusilina* sp. and *Fusilinella?* sp. Thompson also tentatively identified *Millerella?* sp. in the chert at the Little Warm Springs Creek locality.

In the collections under study, *Textularia* cf. *T. grahamensis* and *Kirkbya?* sp. are present from the Shell Canyon locality, and a fusiform fusilinid, either *Fusilina* sp. or *Triticites* sp., is present in collections from the Little Warm Springs Creek locality. The preservation of the fusilinids leaves some doubt as to the type of fluting of the septa.

The photographs were taken by Howard Broock in the Department of Geology at Bowling Green State University.

LOCALITIES

Locality 1. Little Warm Springs Creek Canyon, secs. 14, 15, T. 41 N., R. 107 W., Fremont County, Wyoming. The collection was made from a zone of chert nodules contained in fine-grained sandstone about 15 feet above the base of the formation on the north side of the stream.

Locality 2. Shell Creek Canyon, sec. 17, T. 53 N., R. 90 W., Big Horn County, Wyoming. The collection was made from a bed, 5–10 feet below the top of the Tensleep sandstone, containing maroon chert. This locality is next to the road leading into the canyon.

SYSTEMATIC PALEONTOLOGY

Phylum BRACHIOPODA
Genus DERBYIA Waagen, 1884
DERBYIA CRASSA (Meek & Hayden)
Pl. 91, fig. 8

Orthisina crassa MEEK & HAYDEN, 1859, Proc. Philadelphia Acad. Nat. Sci., p. 261.
Derbya crassa GIRTY, 1915, U. S. Geol. Survey,

Bull. 544, p. 54–58, pl. 6, figs. 1–1c (this paper contains a complete synonymy up to this date); MORNINGSTAR, 1922, Ohio Geol. Survey, 4th ser., Bull. 25, p. 176, 177, pl. 7, figs. 9,10; KELLY, 1930, Jour. Paleontology, v. 4, p. 138, pl. 11, fig. 4; DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2d ser., Bull. 5, p. 79–83, pl. 3, figs. 1–12, text fig. 3.

Derbyia crassa COOPER (in SHIMER & SHROCK), 1944, Index Fossils of North America, p. 345, pl. 133, figs. 20,21.

Several specimens, mostly fragmentary, are present for study. The shells are medium-sized, biconvex, and subquadrangular in outline. The greatest width is at or just anterior to the hinge-line. The most nearly complete specimen is 22.5 mm. wide and 18.0 mm. long. The beaks are low and not pronounced. The surface of the valves is marked by numerous growth lines, some of which are pronounced. Narrow, radial, subangular lirae ornament the valves. The lirae increase in size and number as they approach the anterior margin. The newer lirae are lower than those which extend across the entire surface.

Remarks.—Although some variety in the shape of the shell is present in these specimens, it is not pronounced.

Occurrence.—Tensleep sandstone, locality 1.

Genus LINOPRODUCTUS Chao, 1927
LINOPRODUCTUS PRATTENIANUS (Norwood & Pratten)
Pl. 91, figs. 14,15

Productus prattenianus NORWOOD & PRATTEN, 1855–58, Jour. Philadelphia Acad. Nat. Sci., v. 3, p. 17, pl. 1, figs. 10a–d; MEEK, 1872, U. S. Geol. Survey Nebraska, Final Rept., p. 163, pl. 2, figs. 5a–c; pl. 5, fig. 13; pl. 8, figs. 10a,b.

Productus aequicostatus SHUMARD, 1855, Geol. Rept. Missouri, v. 1, p. 201, pl. C, fig. 10.

Linoproductus prattenianus DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2d ser., Bull. 5, p. 241–244, pl. 24, figs. 4–5b; pl. 27, figs. 1–5,9; COOPER (in SHIMER & SHROCK), 1944, Index Fossils of North America, p. 351, pl. 137, fig. 31; BURK, 1954, Jour. Paleontology, v. 28, p. 9, pl. 1, figs. 36,37.

Productus cora of authors, in part.

This species is represented by the largest number of specimens in the collections. The shell is medium to large in size. The greatest width is at or just anterior to the hinge-line. The most nearly complete specimen, partly embedded in matrix, is 39.0 mm. wide and 42.1 mm. long. The beak of the pedicle valve is strongly convex. Its surface is marked by numerous fine costae which increase slightly in size as they approach the anterior margin. The costae increase in number by bifurcation but this feature is not common. The lateral areas of the umbonal slope and the ears are coarsely wrinkled. Numerous small spine bases are carried by the costae. Most of the specimens, with ears exposed, show two irregularly arranged rows of spines on the ears. On one fragmentary specimen, the spines are arranged in three irregular rows. Spines on the rest of the valve are arranged in a rough quincunx manner.

The brachial valve, including the trail, is strongly concave. The interior surface shows a low thin medial septum, bordered in the posterior portion by two medium-sized tasselate scar areas. The posterior portion of the surface is smooth except for the coarse wrinkles at the ears.

Remarks.—The morphological features of all the specimens, except possibly one, are the same as described for the type specimens. One specimen, bearing three rows of spines on the ear instead of two rows, may belong in a different taxonomic group, but because of its fragmental nature is not separated here. Specimens of *Linoproductus* from the Cherokee shale of the northern midcontinent also show three rows of spines and are thought to be a distinct species.

Occurrence.—Tensleep sandstone, locality 1.

Genus DICTYOCLOSTUS Muir-Wood, 1930
DICTYOCLOSTUS PORTLOCKIANUS (Norwood & Pratten)
Pl. 91, fig. 13

Productus portlockianus NORWOOD & PRATTEN, 1854, Jour. Philadelphia Acad. Sci., v. 3, p. 15, pl. 1, figs. 9a–c.

Dictyoclostus portlockianus DUNBAR & CONDRA, 1932, Nebraska Geol. Survey., 2d ser., Bull. 5, p. 215–217, pl. 33, figs. 1–3; COOPER (in SHIMER & SHROCK), 1944, Index Fossils of North America, p. 350, pl. 136, figs. 7,8. [non] *Dictyoclostus portlockianus* BURK, 1954, Jour. Paleontology, v. 28, p. 9, pl. 1, figs. 29,30.

One specimen, which is poorly preserved, is present. It is partly embedded in matrix, and most of the exposed shell has been exfoliated. Projected dimensions show a width of 46.0 mm. and a length of 40.8 mm. The greatest width is along the hinge-line. The

beak of the pedicle valve overhangs the hinge-line slightly. The pedicle valve is not geniculate but is broadly convex with a wide, rather shallow, medial sulcus. At a width of 10.0 mm., 10–12 costae are present on the anterior portion of the pedicle valve. Several large spine bases are scattered over the posterior portion of the pedicle valve. A row of smaller spines are present on the ears following the hinge-line, and a row of large spines follow a conspicuous wrinkle at the base of the umbonal slope. Portions of the interior surface of the brachial valve appear in areas where parts of the pedicle valve are missing.

Remarks.—Although this specimen is poorly preserved, the general shape of the pedicle valve, size and number of costae, and distribution of spines show its relationship to the type specimens. The pedicle valve is not as highly convex as in *Dictyoclostus hermosanus* (Girty). Specimens referred by Burk (1954) to this species appear to resemble *D. gallatinensis* (Girty).

Occurrence.—Tensleep sandstone, locality 2.

DICTYOCLOSTUS HERMOSANUS (Girty)
Pl. 91, figs. 10–12

Productus semireticularis var. *hermosanus* GIRTY, 1923, U. S. Geol. Survey, Prof. Paper 16, p. 358,359, pl. 2, figs. 1–4b; DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2d ser., Bull. 5, p. 220.

This species is represented by six specimens, three of which are the interior surfaces of the brachial valve. The pedicle valve is strongly convex with a rather narrow but pronounced medial sulcus. The greatest width at the hinge-line is 40.0 mm. and the length is 38.5 mm. The posterior portion of the valve is coarsely rugose. Costae number 13 in the width of 10.0 mm. on the anterior portion of the valve. A few large spine bases are borne on the costae. Spines in the region of the ears can not be seen because of the poor preservation of the specimens.

The interior of the brachial valve shows two large tasselate scar areas which are raised above the general surface of the valve. A heavy ridge beginning at the base of the cardinal process runs parallel to the hinge-line then curves anteriorly in the region of the ears. Large triangularly shaped brachial impressions are slightly elevated above the valve surface. The areas of the valve adjacent to the posterior margins are pitted. A low medial septum is present although not well preserved.

Remarks.—The convexity of the pedicle valve distinguishes this species from *Dictyoclostus portlockianus* (Norwood & Pratten).

Occurrence.—Tensleep sandstone, locality 1.

DICTYOCLOSTUS GALLATINENSIS (Girty)
Pl. 91, figs. 6,7

Productus gallatinensis GIRTY, 1899, U. S. Geol. Survey, Mon. 32, p. 533, pl. 68, figs. 7a–c, 11a–d; ——, 1903, U. S. Geol. Survey, Prof. Paper 16, p. 361, pl. 3, figs. 4–8a; MATHER, 1915, Bull. Sci. Lab. Denison Univ., v. 18, p. 163, pl. 9, figs. 4–5b.

Four specimens are referable to this species. The shell is small with a length of 14.0 mm. and a width of 13.5 mm. The pedicle valve is strongly arched and shows a pronounced medial sulcus, except on one specimen. The beak is small and overhangs the hinge-line slightly. The shell is partly exfoliated but shows indications of relatively coarse costae for the size of the shell, six in the width of 5.0 mm. Relatively large spines, arranged in a quincunx pattern, are borne on the costae on the anterior portion of the valve. Portions of the ears are present, and at least one row of spines borders the hinge-line. At least three spines are arranged in a row along the base of the umbonal slope. The pedicle valve has a long trail.

Remarks.—These specimens appear to agree closely with those described by Girty (1903) from Colorado. The size of the shell and the costae, together with the arrangement of the spines, is diagnostic.

Occurrence.—Tensleep sandstone, locality 2.

Genus SPIRIFER Sowerby, 1814–18

SPIRIFER OPIMUS Hall
Pl. 91, figs. 4,5

Spirifer opimus HALL, 1858, Rept. Geology of Iowa, v. 1, pt. 2, p. 711, pl. 28, figs. 1a–b; GIRTY, 1903, U. S. Geol. Survey, Prof. Paper 16, p. 46, 81, 382, 383, 384; MATHER, 1915, Bull. Sci. Lab. Denison Univ., v. 18, p. 185, pl. 12, figs. 7–7c; DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2d ser., Bull. 5, p. 320–

322, pl. 41, figs. 10–11c; BURK, 1954, Jour. Paleontology, v. 28, p. 11, pl. 1, figs. 16–22; MORNINGSTAR, 1922, Ohio Geol. Survey, 4th ser., Bull. 25, p. 188, pl. 9, figs. 13–20.

This species is relatively common in the collection. The shell is biconvex with the greatest width just anterior to the hinge-line. The width is 24.0 mm. and the length 17.0 mm. The beaks are small, overhanging the hinge-line slightly. A distinct medial fold is present on the brachial valve with a corresponding sulcus on the pedicle valve. The surface of both valves is covered with non-fasciculate costae. The pedicle valve normally has 13 or 14 costae on the lateral areas and five costae in the sulcus. The brachial valve has 11 costae on the lateral areas and four costae on the fold. Concentric lines of growth mark the surface.

Remarks.—*Spirifer opimus* is closely allied with *S. rockymontanus* Marcou. It differs from the latter in having a less pronounced fold and sulcus and in bearing fewer costae on the fold and sulcus.

Occurrence.—Tensleep sandstone, locality 1.

Genus NEOSPIRIFER Fredericks, 1919
NEOSPIRIFER CAMERATUS (Morton)
Pl. 91, fig. 9

Spirifer cameratus MORTON, 1836, Am. Jour. Sci., 1st. ser., v. 29, p. 32, 150, pl. 2, fig. 3; GIRTY, 1915, U. S. Geol. Survey, Bull. 544, p. 87–91, pl. 9, figs. 4–4b (this paper contains a complete synonymy up to this date); ——, 1927, U. S. Geol. Survey, Prof. Paper 152, pl. 27, figs. 24–27; MORNINGSTAR, 1922, Ohio Geol. Survey, 4th ser., Bull. 25, p. 188, pl. 9, figs. 11,12; KELLY, 1930, Jour. Paleontology, v. 4, p. 147, pl. 11, fig. 17.

Neospirifer cameratus DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2d ser., Bull. 5, p. 334–336, pl. 39, figs. 4,6–9b; COOPER (in SHIMER & SHROCK), 1944, Index Fossils of North America, p. 325, pl. 125, figs. 5,6.

Two specimens are available for description. Both are fragmentary and poorly preserved. The shell is medium-sized with the greatest width at the hinge-line. The width is about 43.5 mm. and the length about 26.0 mm. measured on the brachial valve. The valves are convex. A pronounced fold is present on the brachial valve. The surface of the valve is covered by numerous low rounded costae which increase in number by bifurcation but are not prominently grouped in bundles. Sixteen costae can be counted on the lateral area of the brachial valve, although the actual number is probably greater than sixteen. They are not well preserved. The number of costae on the fold can not be determined.

Remarks.—Specimens of *Neospirifer goreii* (Mather) are not as alate as *N. cameratus*. *N. triplicatus* (Hall) has well-bundled costae which are not present on these specimens.

Occurrence.—Tensleep sandstone, localities 1 and 2.

Genus PHRICODOTHYRIS George, 1932
PHRICODOTHYRIS PERPLEXA? (McChesney)

Spirifer perplexa MCCHESNEY, 1860, Desc. New Species Fossils, p. 43. (Priv. Pub.)

Squamularis perplexa GIRTY, 1915, U. S. Geol. Survey, Bull. 544, p. 92–94, pl. 11, figs. 1–3a (this paper contains a complete synonymy up to this date); MORNINGSTAR, 1922, Ohio Geol. Survey, 4th ser., Bull. 25, p. 191, pl. 9, figs. 26,27; DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2d ser., Bull. 5, p. 313–317, pl. 42, figs. 5–8.

Phricodothyris perplexa COOPER (in SHIMER & SHROCK), 1944, Index Fossils of North America, p. 328, pl. 126, figs. 9,10.

Two fragmentary valves, one of which is a juvenile specimen and one considerably larger, were found embedded in matrix. Both specimens show convex valves and appear to have a suboval shape. No determination of over-all dimensions could be made. Concentrically arranged ridges cross the valves. The presence of spine bases on the ridges can be distinguished although they are not well preserved.

Remarks.—The distinguishing concentric ridges bearing spine bases are diagnostic of the genus *Phricodothyris*, but the specimens are questionably placed in this species because of their fragmentary nature.

Occurrence.—Tensleep sandstone, locality 2.

Genus COMPOSITA Brown, 1849
COMPOSITA sp.

One specimen, very poorly preserved, is present. The general shape of the shell indicates a broadly convex brachial valve with only slight indications of a medial fold. The shell bears no trace of ornamentation.

Remarks.—The general shape of the shell and lack of ornamentation are the basis for this generic designation but the state of

preservation does not allow a specific identification.

Occurrence.—Tensleep sandstone, locality 1.

Phylum MOLLUSCA
Class GASTROPODA
Genus STRAPAROLUS Montfort, 1810
Subgenus EUOMPHALUS Sowerby, 1814
STRAPAROLUS (EUOMPHALUS) cf. S. (E.) PLUMMERI Knight
Pl. 91, figs. 1,2

Euomphalus n. sp. PLUMMER & MOORE, 1921, Texas Univ., Bull. 2132, pl. 19, figs. 12–15, *fide* [Knight, J. B., 1934, Jour. Paleontology, v. 8, p. 152.]
Straparollus (*Euomphalus*) *plummeri* KNIGHT, 1934, Jour. Paleontology, v. 8, p. 152, pl. 22, figs. 3a–h; pl. 26, fig. 7; ——, 1944, (in SHIMER & SHROCK), Index Fossils of North America, p. 465, pl. 188, figs. 32,33.

Shell small to medium-sized, discoid, and pseudoplanispirally coiled. Umbilicus broad and relatively shallow on the upper surface. The umbilicus on the basal side is deeper but not as broad as on the upper surface. Earlier volutions show a more circular cross-section shape while the later whorls are subquadrate in section. The outer lateral surface is gently convex. A sharp ridge forms the junction between the outer lateral surface and the upper surface of the whorl. From the ridge, the upper whorl surface slopes steeply in a concave fashion to meet the outer surface of the preceding volution. The outer whorl surface of the inner volution rises above the upper surface of the preceding volution before sloping concavely into the next volution. The upper surface of the volutions on the basal side of the shell are convexly curved. The largest specimen shows a maximum diameter of 24.0 mm. The number of whorls could not be determined. No surface ornamentation is observable.

Remarks.—The apparent lack of strong surface ornamentation and the general shape of the cross-section in the outer volutions distinguish this species. Other species of the subgenus *Euomphalus* show pronounced surface ornamentation such as nodes or two carinate ridges, or have a different cross-section shape. The state of preservation leaves some doubt as to the exact specific designation.

Occurrence.—Tensleep sandstone, locality 1.

Class SCAPHOPODA
Genus DENTALIUM Linnaeus, 1758
Subgenus PLAGIOGLYPTA Pilsbry, 1898
DENTALIUM (PLAGIOGLYPTA) sp.

One fragmental specimen showing a slightly curved shape and smooth outer shell surface is present in the collection. The preservation by replacement is of a very coarse texture and no growth lines are visible.

Remarks.—The specimen cannot be identified specifically because of its fragmental nature and poor preservation.

Occurrence.—Tensleep sandstone, locality 1.

Phylum ARTHROPODA
Genus AMEURA J. M. Weller, 1936
AMEURA sp.
Pl. 91, fig. 3

A nearly complete pygdium, which is upside down and preserved in chert, forms the basis for this identification. The axial lobe is relatively narrow and highly arched with flattened sides. A broad smooth flange is present and shows the presence of intersegmental furrows anteriorly. At least 10 pleural segments and 17 axial segments are present. The pygidium is narrowly rounded posteriorly and is slightly wider than long. The specimen is slightly distorted but shows a width of 16.0 mm. and a length of 14.0 mm.

Remarks.—The narrow axial lobe and the larger number of segments distinguishes this specimen from those belonging to the genus *Ditomopyge* J. M. Weller with which it is most commonly confused.

Occurrence.—Tensleep sandstone, locality 1.

REFERENCES

AGATSTON, R. S., 1957, Pennsylvanian of the Wind River Basin: Wyoming Geol. Assoc., Guidebook, 12th Ann. Field Conf., p. 29–33.
BRAINERD, A. E. & KEYTE, I. A., 1927, New faunal evidence from the Tensleep Formation: Jour. Paleontology, v. 1, p. 173,174, pls. 29,30.
BRANSON, C. C., 1939, Pennsylvanian formations of central Wyoming: Geol. Soc. America, Bull., v. 50, p. 1199–1226, 3 pls.
BRANSON, E. B. & GREGER, D. K., 1918, The Amsden formation of the east slope of the

Wind River Mountains of Wyoming and its fauna: Geol. Soc. America, Bull., v. 29, p. 309–326, pls. 18–19.

BURK, C. A., 1954, Faunas and age of the Amsden formation in Wyoming: Jour. Paleontology, v. 28, p. 1–16, pl. 1.

DUNBAR, C. O. & CONDRA, G. E., 1932, Brachiopoda of the Pennsylvanian of Nebraska: Nebraska Geol. Survey, 2d ser., Bull. 5, 377 p., 44 pls.

GIRTY, G. H., 1903, The Carboniferous formations and faunas of Colorado: U. S. Geol. Survey, Prof. Paper 16, 546 p., 10 pls.

——, 1927, Description of Carboniferous and Triassic fossils in geography, geology and mineral resources of part of southeastern Idaho by G. B. Mansfield: U. S. Geol. Survey, Prof. Paper 152, p. 411–446, pls. 22–25,27,30.

KEEFER, W. R., 1957, Geology of the Du Noir area, Fremont County, Wyoming: U. S. Geol Survey, Prof. Paper 294-E, 221 p.

KNIGHT, J. B., 1934, The gastropods of the St. Louis, Missouri Pennsylvanian outlier: VII. The Euomphalidae and Platyceratidae: Jour. Paleontology, v. 8, p. 139–166, pls. 20–26.

SHIMER, H. W. & SHROCK, R. R., 1944, Index fossils of North America: John Wiley and Sons, Inc., 837 p., 303 pls.

THOMAS, H. D., 1948, Summary of Paleozoic stratigraphy of the Wind River Basin, Wyoming: Wyoming Geol. Assoc., Guidebook, 3rd Ann. Field Conf., p. 79–95.

WELLER, J. M., 1936, Carboniferous trilobite genera: Jour. Paleontology, v. 10, p. 704–714, pl. 95.

——, 1937, Evolutionary tendencies in American Carboniferous trilobites: Jour. Paleontology, v. 11, p. 337–346.

EXPLANATION OF PLATE 91

FIGS. *1,2—Straparolus* (*Euomphalus*) cf. *S.* (*E.*) *plummeri* Knight. An external mold and an internal mold (BGSU 1046, 1045) from locality 1, ×1.

3—Ameura sp. Interior of pygidium (BGSU 1050) from locality 1, ×1.

4,5—Spirifer opimus Hall. Brachial and pedicle valves (BGSU 1031, 1030) from locality 1, ×1.

6,7—Dictyoclostus gallatinensis (Girty). Two pedicle valves (BGSU 1026, 1027) from locality 2, ×2.

8—Derbyia crassa (Meek & Hayden). Fragmentary pedicle valve (BGSU 1000) from locality 1, ×1.

9—Neospirifer cameratus (Morton). Interior mold of a pedicle valve (BGSU 1040) from locality 2, ×1.

10–12—Dictyoclostus hermosanus (Girty). Interior of brachial valve, a pedicle valve and a brachial interior (BGSU 1020, 1021, 1022) from locality 1, ×1.

13—Dictyoclostus portlockianus (Norwood & Pratten). Badly exfoliated pedicle valve (BGSU 1019) from locality 2, ×1.

14,15—Linoproductus prattenianus (Norwood & Pratten). Brachial interior with a portion of the umbo of the pedicle valve still in place and a pedicle valve (BGSU 1004, 1005) from locality 1, ×1.

1

2

3

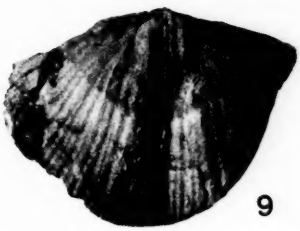
4

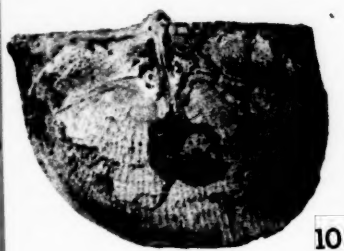
5

6

7

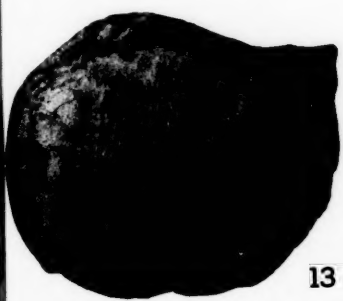
8

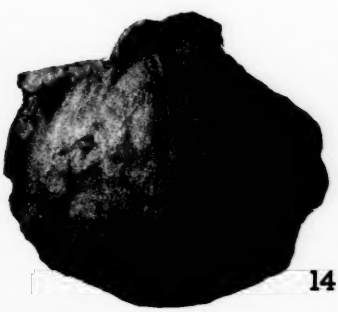

9


10

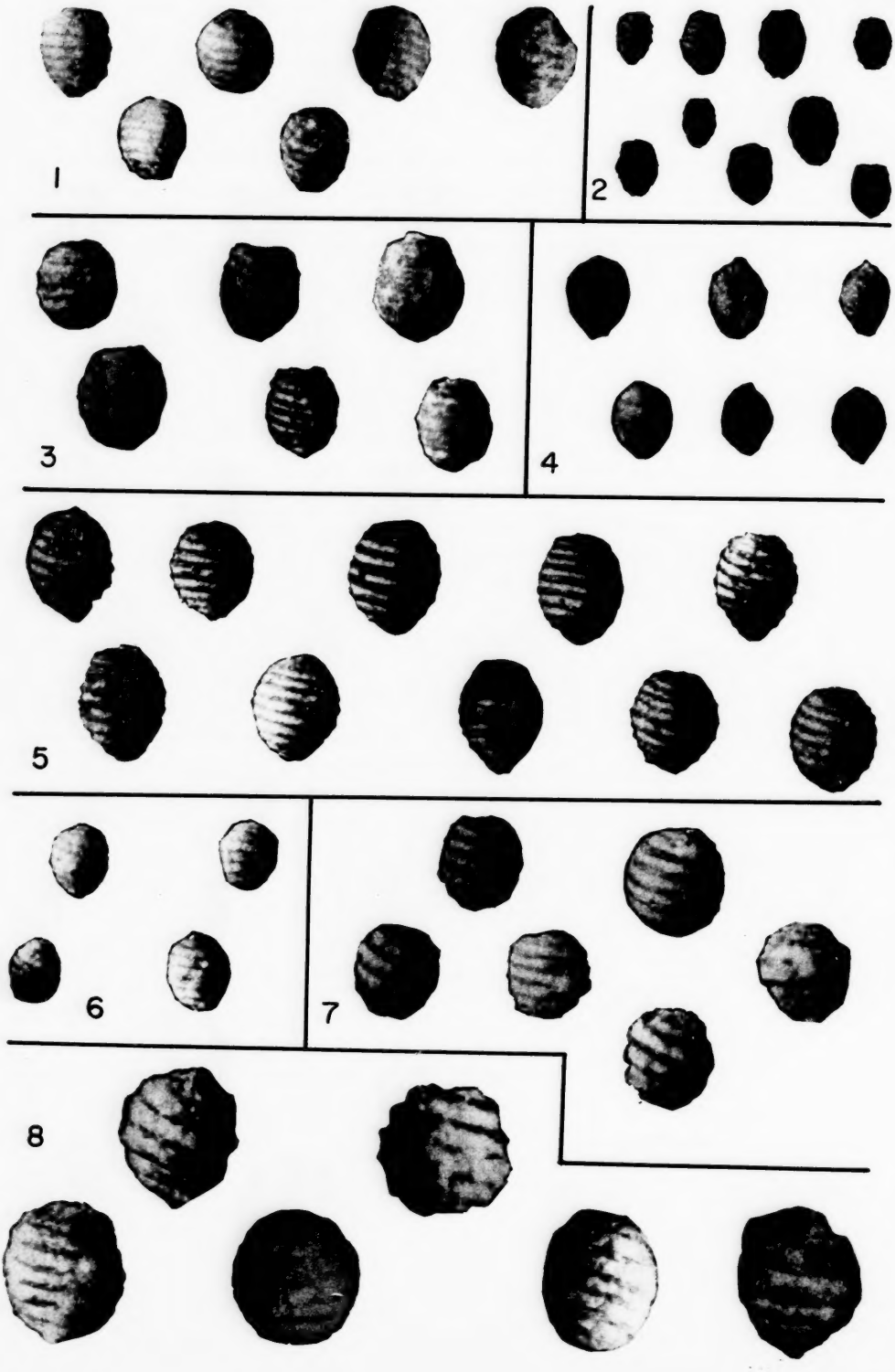
11

12


13


14

15


1
2
3
4
5
6
7
8

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 717–726, PL. 92, 10 TEXT-FIGS., JULY, 1960

POPULATION STUDY OF CHAROPHYTE SPECIES, MORRISON FORMATION, COLORADO

CHARLES A. ROSS
Yale University, New Haven, Connecticut

ABSTRACT—Populations of eight species of charophyte gyrogonites from the Morrison formation (Jurassic), Front Range area, Colorado, collected in successive samples in six measured sections, show differences in average size, variation in size, and in tightness of spiralling. These differences, the same kind as are found among Recent charophyte subspecies, are suggestive of genetic changes resulting from evolution. The relative abundance of species in samples is apparently controlled by ecological conditions similar to those operative in distributing Recent Charophyta.

The proposed correlation of the six sections is based on population characteristics of the more abundant species, *Aclistochara bransoni* Peck, *Praechara symmetrica* Peck, and *Latochara latitruncata* (Peck).

INTRODUCTION

CHAROPHYTA, freshwater algae, are among the more abundant fossils in the Morrison formation in the Front Range region of Colorado, and because of their common association with gastropods, ostracods, and dinosaurs are of considerable interest. The ecological requirements of Recent Charophyta are known in detail (Wood, 1950, 1952). The charophytes in the Morrison formation are taxonomically similar to Recent genera and probably required comparable environments.

These algae are essentially a freshwater group, but several species in different genera are able to tolerate brackish water up to 15 0/00 salt in shore ponds and lagoons. Charophytes commonly are the first flora to invade newly formed ponds and may remain until the ponds are filled by sediments. Their dispersal from one pond to another, primarily by currents or birds, is rapid. An example of the latter mode of dispersal is found in west Texas where steel water tanks several miles apart supplied with water from windmills, and 20 to 30 miles from the nearest natural pond, contain abundant mature charophytes one year after the tanks have been cleaned. A similar mode of dispersal is also possible for the Jurassic charophytes, since primitive birds are known from rocks of this period.

The gyrogonite, the most common part of the alga preserved, is a part of the oogonium, female reproductive organ. It consists of calcified spiral tubes of the oogonium and the internal chamber. Fossil gyrogonites, considered in this investigation, have proven to be the most useful part of charophytes for taxonomic studies. The antheridium, male reproductive organ, and the vegetative parts of these algae are less commonly preserved and are less studied by taxonomists.

This study investigates the variation in eight previously described species of Charo-

EXPLANATION OF PLATE 92
All figures ×10

FIGS. *1*—*Praechara symmetrica* Peck. Six specimens from sample 4, Red Hill section.
2—*Obtusochara mädleri* Peck. Nine specimens from sample 4, Red Hill section.
3—*Aclistochara bransoni* Peck. Six specimens from sample 4, Red Hill section.
4—*Latochara latitruncata* (Peck). Six specimens from sample 9, Loveland section.
5—*Stellochara obovata* (Peck). Ten specimens from sample 7, Loveland section.
6—*Praechara voluta* (Peck). Four specimens from sample 3, Red Hill section.
7—*Aclistochara complanata* Peck. Six specimens from sample 10, Ingleside section.
8—*Aclistochara latisulcata* Peck. Six specimens from sample 10, Ingleside section.

phyta from six sections measured in the Front Range area, Colorado. Populations of gyrogonites of each species were studied from samples in these measured sections. Their distribution and abundance and their changes in variation and in size are considered in terms of their environment, evolution, and for possible use as correlation fossils.

The Morrison formation has broad areal extent reaching from New Mexico to Montana and from Kansas to Utah. As is true of other Jurassic rocks in this area, the formation thickens and has mainly sandstones and siltstones in its southwestern portions, and it thins and becomes shaly and limy to the north and east. In the Front Range area, Colorado, it consists mainly of lenses of sandstone, siltstone, claystone, shale, and limestone. The discontinuity of these lenses is a striking feature of the Morrison formation. Individual beds can seldom be traced laterally more than a few hundred feet. Diastems within the formation are apparently of local importance. Thus, lithologic units are of only local significance for correlation purposes.

A study of fossil algae from different parts of the Morrison formation was suggested by J. Chronic, University of Colorado, as a possible approach to correlation of these rocks. D. L. Eicher, University of Colorado, aided in portions of the field work during the autumn of 1953.

Most of the previous charophyte studies from this formation have been of samples from isolated localities in Colorado, Utah, and Wyoming. Peck (1937) was the first to describe Charophyta from this formation. He restudied them along with other Mesozoic Charophyta in 1957 (Peck, 1957). Ott (1958) studied charophytes from Utah and Colorado and measured many specimens from both eastern and western facies of the Morrison formation.

Presentation of Data

Scatter diagrams showing variations within each population were plotted for each gyrogonite, height (ordinate), and width (abscissa). The populations fall within only a small portion of the graph so that only this small portion, bounded by a square grid and lying between the abscissa and ordinate coordinates of 0.25 mm. and 0.50 mm., is given in the text-figures. The amount of spiral in the outer five cells is given as the number of whorls visible in lateral view divided by five.

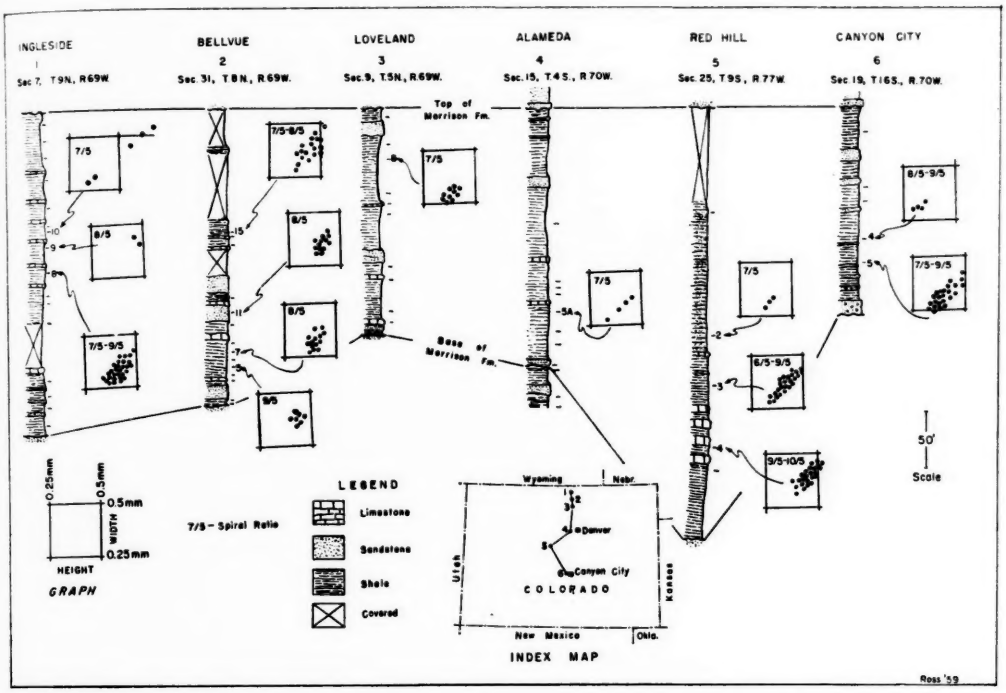
DISTRIBUTION

The six outcrop localities of the Morrison formation studied along the eastern flank of the Colorado Front Range are from Ingleside near the Colorado-Wyoming boundary on the north to Canyon City in the south, and the single locality to the west in South Park. The six sections are, from north to south, Ingleside, Bingham Hill near Bellvue, Loveland, north of the town of Morrison on the Alameda Parkway, Red Hill in South Park, and Canyon City. Most of the samples are from limy shales.

Charophyta are common throughout almost the entire sequence in the Ingleside and Bellvue sections, but in the sections to the south and west they are present only in the lower third of the formation. This difference may be related to the greater distribution of fresh water limestones in the northern sections and may reflect the paleoecologic conditions during Morrison deposition (Text-fig. 1).

Aclistochara bransoni Peck, *Praechara symmetrica* Peck, and *Latochara latitruncata* (Peck) are the most abundant species in the collections. Locally, as in the Loveland section, *Stellatochara obovata* (Peck) and *Aclistochara complanata* Peck are abundant, but at other localities these last two species and *Praechara voluta* (Peck) commonly form only a small percentage of the flora. *Obtusochara mädleri* Peck is known from the Red Hill samples. As these Red Hill samples were washed through a 120 mesh screen, and other samples through a 90 mesh screen through which minute gyrogonites such as *O. mädleri* may have been lost, the absence of *O. mädleri* in other sections may be in part due to washing techniques.

Aclistochara bransoni Peck, 1937: (Text-fig. 1; Pl. 92, fig. 3). This species is well represented in most collections. The population from sample 8 of the Ingleside section has seven to nine visible spirals indicating extreme variability in the tightness of spiralling. Populations in samples 9 and 10 of this section are not large enough to be distinc-



TEXT-FIG. *1*—Distribution of and variations in populations of *Aclistochara bransoni* Peck.

tive. Populations from the Bellvue section show gradual decrease in tightness of spiralling but change only slightly in size and size variation in younger strata. The population from sample 8 in the stratigraphic section west of Loveland is composed of gyrogonites smaller in size and more loosely spiralled than those from the Bellvue section. Alameda sample 5A contains only four specimens but they are similar in size and tightness of spiralling to the population from Loveland sample 8.

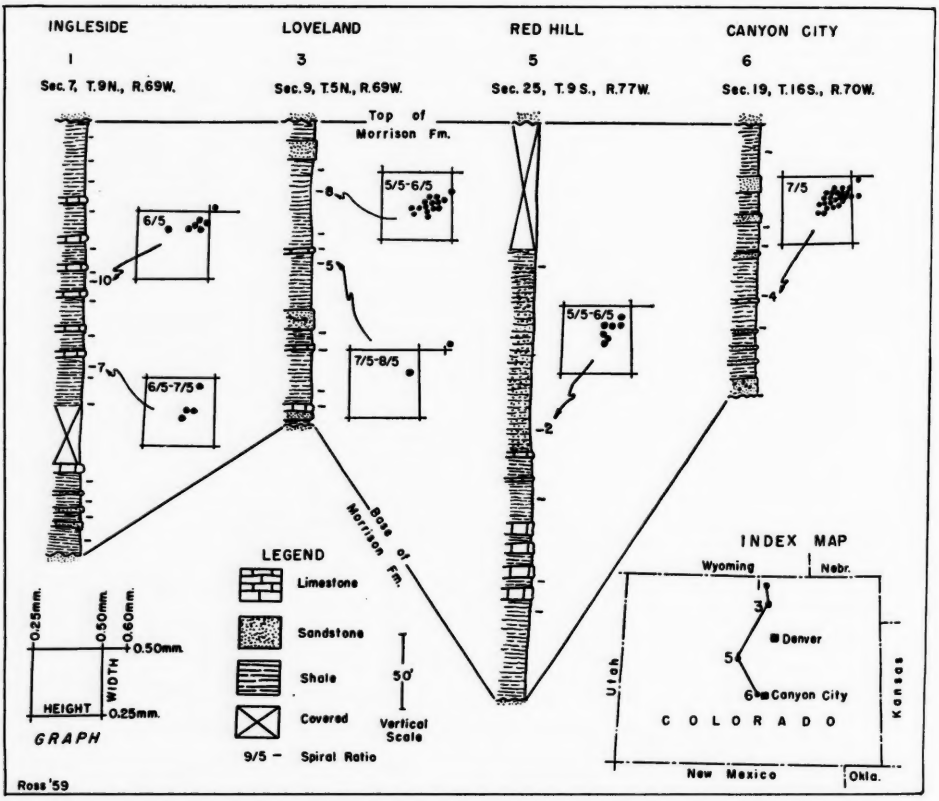
The population of *Aclistochara bransoni* found in the lowest part of the section at Red Hill (sample 4) has a large size range and the gyrogonites are tightly spiralled. The average size in sample 4 is larger than that in the population from sample 3 of this section (50 feet above) in which individuals show large variation in size and tightness of spiralling. In regard to the tightness of spiralling and average size, the population in sample 3 is similar to that from Ingleside sample 8. The scant population in Red Hill sample 2 has gyrogonites of small size having spiral ratios of 7/5 that are probably characteristic of the population.

The population from the lowest part of the Canyon City section has large variations in size and tightness of spiralling. This population is similar to the populations from Red Hill sample 3 and Ingleside sample 8. The population from Canyon City sample 4 has a small average size and is tightly spiralled.

In the succession of beds upwards, the gyrogonites of *Aclistochara bransoni* appear to become less tightly spiralled and slightly smaller.

Aclistochara complanata Peck 1957: (Text-fig. 2; Pl. 92, fig. 7). This species is known from six collections in the Ingleside, Loveland, Red Hill, and Canyon City sections. In higher parts of the sequence, the populations of gyrogonites generally become less tightly spiralled but insufficient data do not permit more concrete conclusions.

Aclistochara latisulcata Peck 1957: (Text-fig. 3; Pl. 92, fig. 8). Although known from single samples in each of the Ingleside,



TEXT-FIG. 2—Distribution of and variations in populations of *Aclistochara complanata* Peck.

Bellvue, Alameda, and Canyon City sections, the size and the spiralling suggest that populations in the Ingleside sample 10 and Canyon City sample 4 are similar and that populations in the Bellvue sample 15 and Alameda sample 1 are similar.

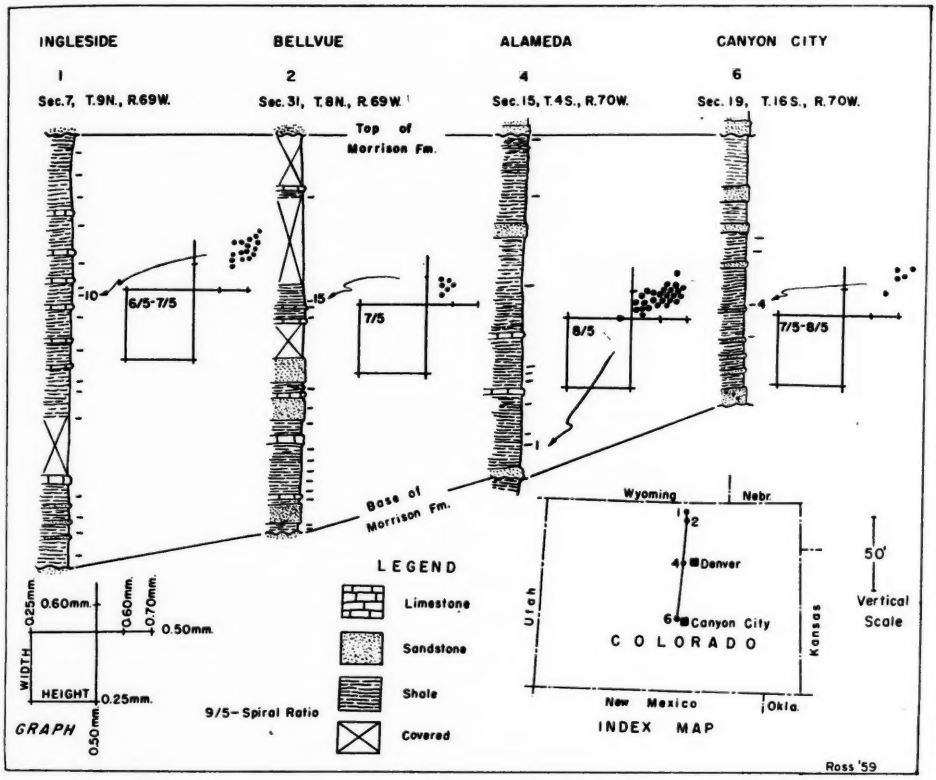
Obtusochara mädleri Peck 1957: (Text-fig. 4; Pl. 2, fig. 2). This small species is known definitely from only the Red Hill section. The population from Red Hill sample 4 indicates the range in size of the species. Populations from collections in younger parts of the sequence suggest a decrease in size and an increase in tightness of spiralling.

Stellatochara obovata (Peck) 1937: (Text-fig. 5; Pl. 92, fig. 5). This species is common in only three samples: Ingleside sample 9, Bellvue sample 15, and Loveland sample 7, although several specimens are known from other collections. The population from Loveland sample 7 includes four specimens which are abnormally narrow, and two specimens which have spiral ratios of 8/5 instead of the normal 10/5.

Latochara latitruncata (Peck) 1937: (Text-fig. 6; Pl. 92, fig. 4). With the exception of the Bellvue section this species is found in a few samples in each of the sections. When present it is usually common, and most other species are absent or rare. The general trend is for populations to increase in size and decrease slightly in tightness of spiralling in samples from younger parts of the sequence.

Praechara voluta (Peck) 1937: (Text-fig. 7; Pl. 92, fig. 6). In samples from the sections, this is the smaller of the two species of *Praechara* but in no single sample are individuals sufficiently abundant to delimit adequately the variation in different populations.

Praechara symmetrica Peck 1957: (Text-



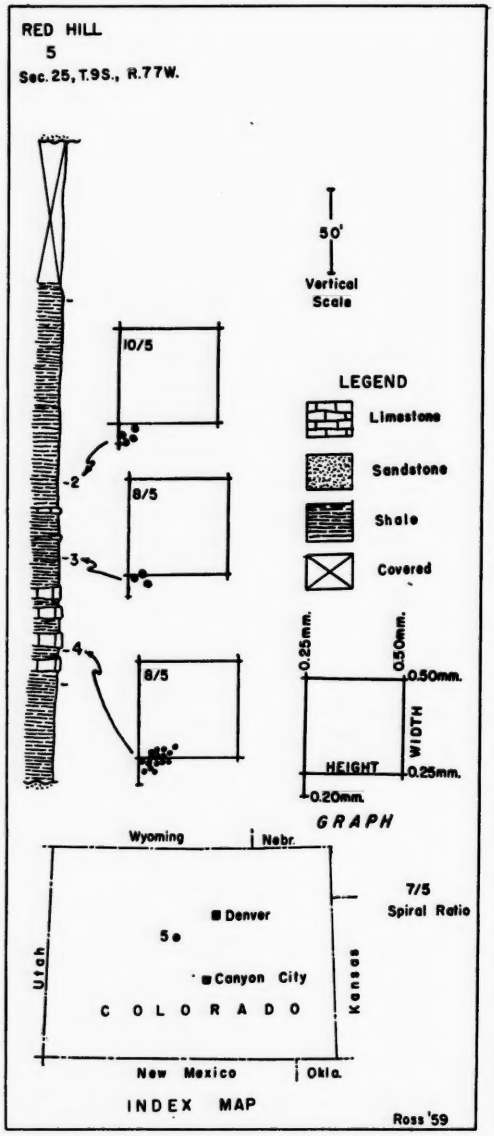
TEXT-FIG. *3*—Distributions of and variations in populations of *Aclistochara latisulcata* Peck.

fig. 8; Pl. 92, fig. 1). Samples of *Praechara symmetrica* from the stratigraphic sections near Ingleside have too few individuals to be useful in determining population characteristics. The two populations from the Bellvue section show a slight increase in size variability and a decrease in tightness of spiralling higher in the section. No specimens of the species were found in the Loveland section. Populations from two samples in the relocated type section of the Morrison formation (Waldschmidt & LeRoy, 1944, p. 1098) on the Alameda Road north of Morrison differ slightly in average size, but the population from the sample higher in the sequence shows increase in tightness of spiralling. Three populations from samples in the Red Hill section indicate a gradual increase in size and in tightness of spiralling in younger strata. Of the two Canyon City samples containing this species, the population higher in the sequence shows an increase in size and tightness of spiralling.

In the Alameda, Red Hill, and Canyon City sections, the gyrogonites of *Praechara symmetrica* show a trend to become more tightly spiralled and larger in average size in younger beds. However the Ingleside and Bellvue samples do not show this trend so markedly.

FAUNAL ASSOCIATIONS AND CORRELATION

Aclistochara bransoni is generally not abundant or is absent is samples having *A. complanata* or *A. latisulcata* (the latter two species occur together in only two collections). *Stellatochara obovata* and *Latochara latitruncata* commonly occur together, but then one of these species is common and the other rare. *L. latitruncata* is most abundant in samples lacking or having few specimens



TEXT-FIG. 4—Distribution of and variations in populations of *Obtusochara mädleri* Peck.

of *A. bransoni*. *Praechara symmetrica* and *A. bransoni* usually occur together in approximately the same abundance, but *P. voluta*, the other associate, is rare throughout the section.

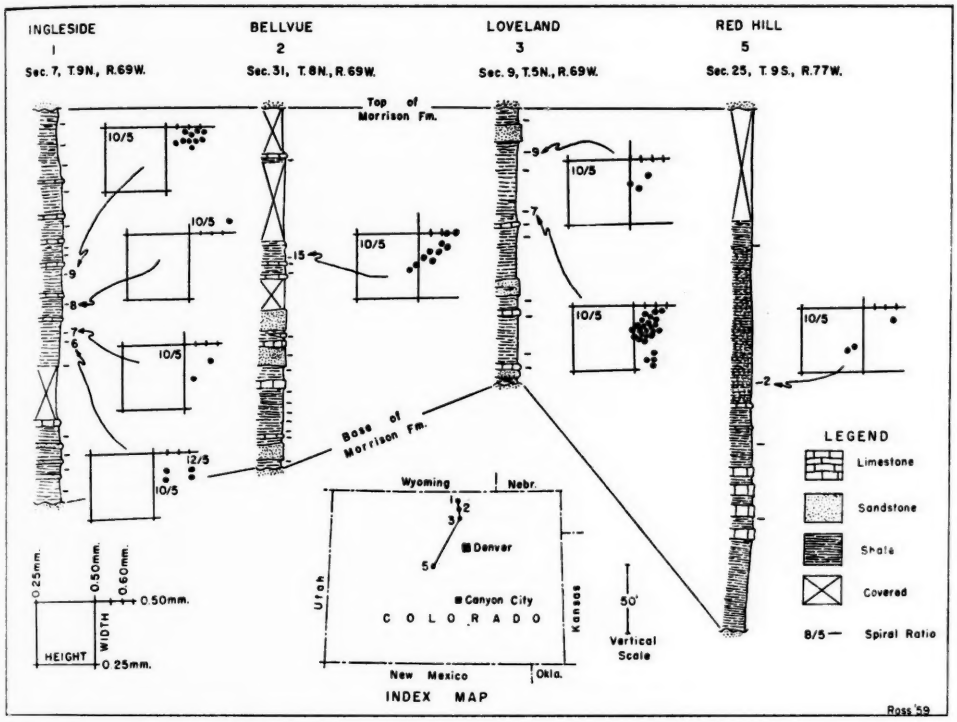
These associations and relative abundance of species suggest ecological controls on the distribution of the species. These controls may be of the type that Wood (1950) discussed for Recent Charophyta where each species is restricted to a definite band around the margin of lakes.

The observed changes in size and spiralling in the populations might be produced by either environmental or genetic causes. If due to environmental causes, these morphologic differences may be interpreted as the direct result of changes in environmental conditions, and the various populations would represent ecologic phenotypes. If this premise is valid, the comparison of these charophyte populations indicates that certain progressive environmental changes were apparently widespread during Morrison deposition and are reflected in the similarity of trends in species in different sections.

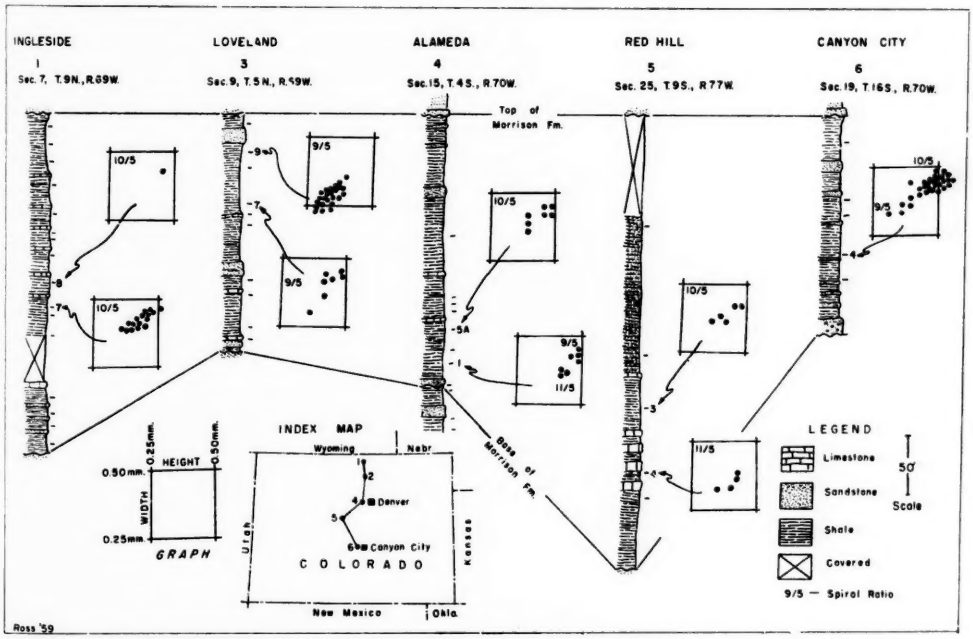
If the observed changes result from genetic change, these populations may represent various steps in an evolutionary progression. These changes are apparently not restricted to local populations within the area, since the more abundant species show similar trends in most of the measured sections suggesting rapid dispersal of characters throughout all populations. Changes in environment exerting selective influence on the genetic composition of the charophyte populations may cause changes in population characteristics similar to those observed in the data.

In an investigation to determine the variability in Recent Charophyta, material previously identified (Department of Biology, University of Colorado) as *Chara* sp., *Chara canescens canescens*, and *Chara canescens cemosa*, was measured and plotted employing the same methods used for the fossil material (Text-fig. 9). These subspecies of Recent *Chara* differ in average size and spiral ratio. Thus the same type of changes that were observed in the fossil material may be used to distinguish Recent subspecies. This suggests that the changes in the fossil populations may be genetic and result from evolutionary changes within the species.

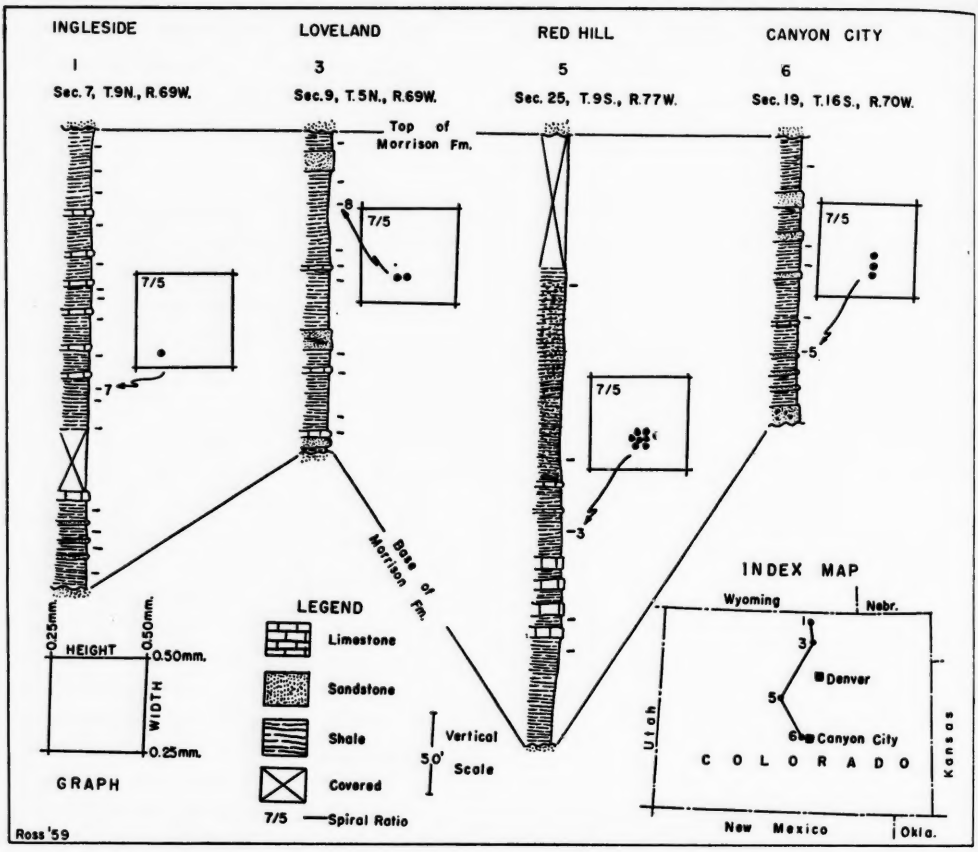
If similar populations represent approximately the same stages in evolutionary progression, it should be possible to use similarities in charophyte populations for correlation purposes, at least in certain regions.



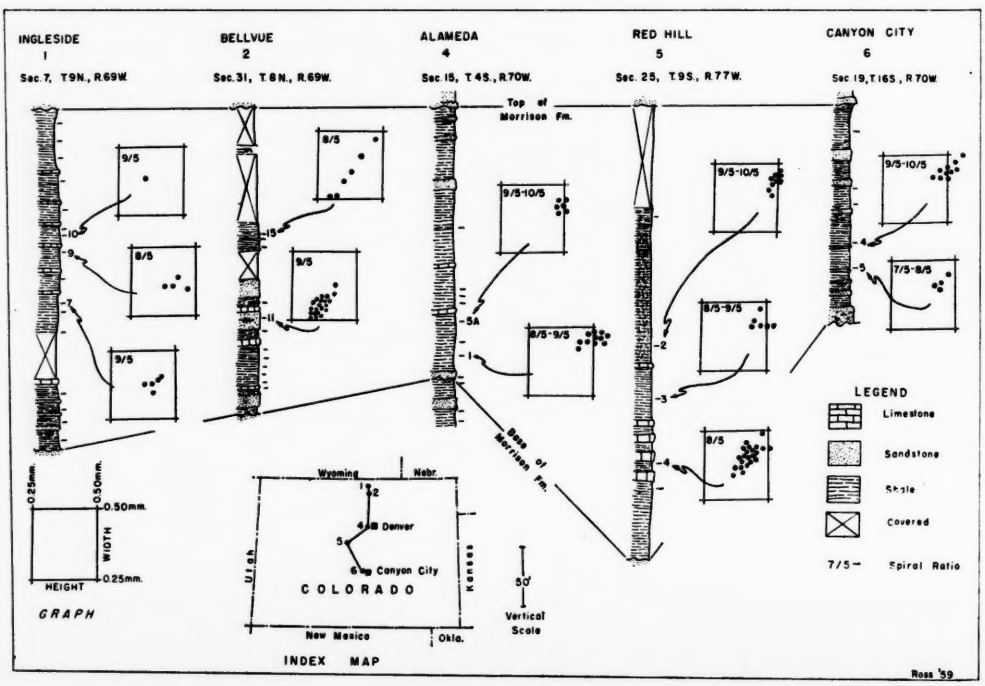
TEXT-FIG. 5—Distribution of and variations in populations of *Stellatochara obovata* (Peck).



TEXT-FIG. 6—Distribution of and variations in populations of *Latochara latitruncata* (Peck).



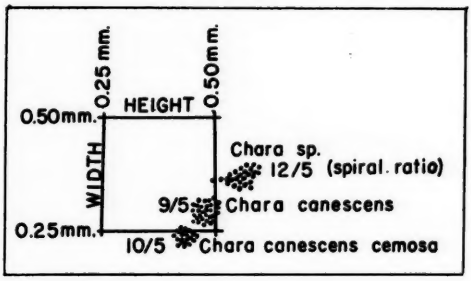
TEXT-FIG. 7—Distribution of and variations in populations of *Praechara voluta* (Peck).



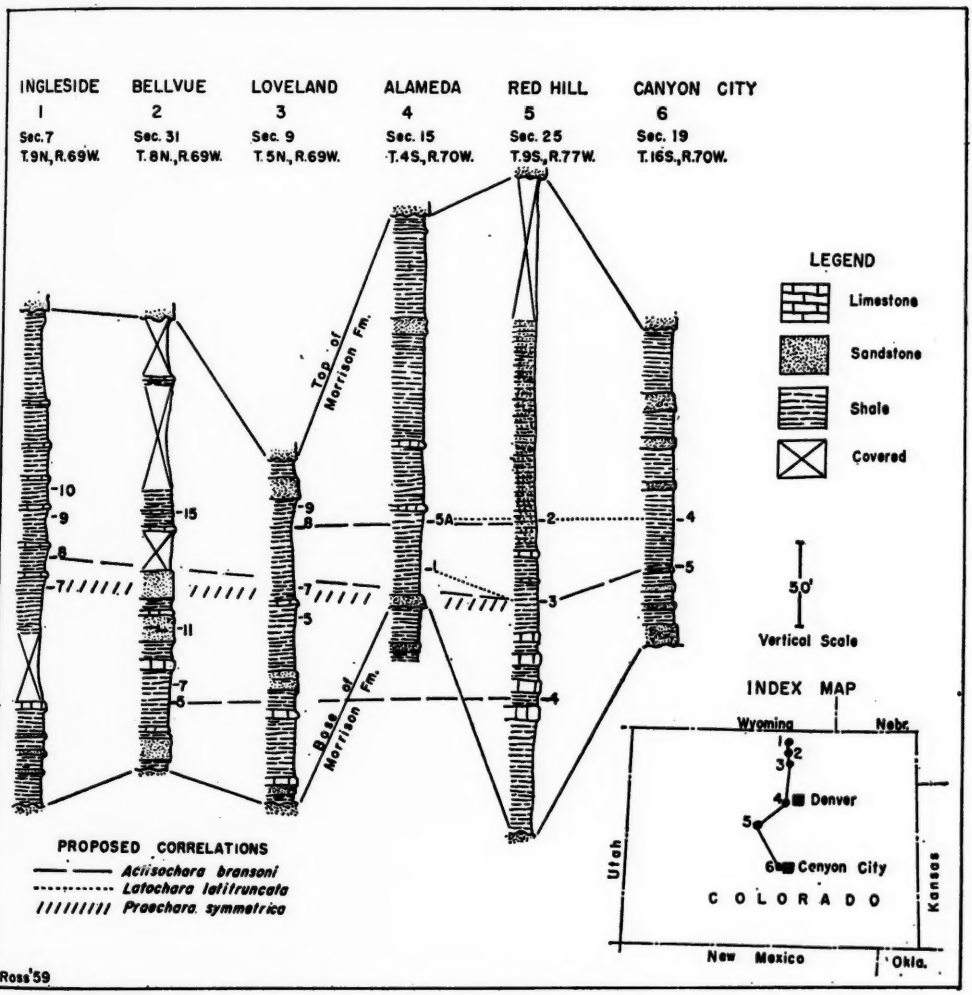
TEXT-FIG. 8—Distribution of and variations in populations of *Praechara symmetrica* Peck.

Text-figure 10 shows a proposed correlation of the six stratigraphic sections based on charophyte populations. The populations of *Praechara symmetrica* with 8 to 9 spirals suggest a correlation between samples from Alameda sample 5A, Red Hill sample 2, and Canyon City sample 4. The similarity in populations from Alameda sample 1 and Red Hill sample 3 also suggest a correlation.

The populations of *Aclistochara bransoni* from Ingleside sample 8, Red Hill sample 3, and Canyon City sample 5, suggest equivalent horizons in these sections. The populations having spiral ratios of 7/5, small size,



TEXT-FIG. *9*—Variation in size and spiral ratio between two subspecies of *Chara canascens* and *Chara* sp.



TEXT-FIG. *10*—Proposed correlation of the six stratigraphic sections of the Morrison formation based on similarities in charophyte populations.

and small variation in size may indicate equivalence between Loveland sample 8, Red Hill sample 2, and Alameda sample 5A. The similarity of the populations from Bellvue sample 5 and Red Hill sample 4 suggest equivalent horizons.

Latochara latitruncata populations from Ingleside sample 8 and Red Hill sample 3 are similar and may represent another equivalent horizon. *Aclistochara complanata* populations from Loveland sample 8 and Red Hill sample 2 are sufficiently similar to suggest a zone of correlation.

Though the correlations are tentative, certain conclusions seem valid. The irregular base and top of these correlated sections in the Morrison formation indicate large differential thicknesses in Morrison deposition, and warping and removal of part of the Morrison sediments is believed to have occurred locally prior to the Dakota sea transgression.

The average size and amount of spiralling in charophyte gyrogonites apparently do change with time. Hence it is believed that charophytes can be useful in regional correlation where an abundance of these fossils is found.

REFERENCES

OTT, H. L., 1958, Stratigraphic distribution of charophytes in the Morrison formation of Colorado and Utah: Master's thesis, University of Missouri.

PECK, R. E., 1937, Morrison Charophyta from Wyoming: Jour. Paleontology, v. 11, p. 83,90.

——, 1957, North American Mesozoic Charophyta: U. S. Geol. Survey, Prof. Paper 294-A, p. 1–44.

WALDSCHMIDT, W. A., & LEROY, L. W., 1944, Reconsiderations of the Morrison formation in the type area, Jefferson County, Colorado: Geol. Soc. America, Bull. 55, p. 1097–1114.

WOOD, R. D., 1950, Stability and zonation of Characeae: Ecology, v. 31, p. 642–647.

——, 1952, An analysis of ecological factors in the occurrence of Characeae of the Woods Hole Region, Massachusetts: Ecology, v. 33, p. 104–019.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 727–730, PLS. 93–94, JULY, 1960

ULTRASONIC VIBRATIONS AS A CLEANING AGENT FOR FOSSILS

CALVIN H. STEVENS, DANIEL H. JONES, AND ROBERT G. TODD
Humble Oil & Refining Co., Houston, Texas

ABSTRACT—Representative fossils from rocks of different ages and lithologies were subjected to relatively low frequency ultrasonic vibrations. An examination of the results showed that the cleaning accomplished is highly successful for many samples and that detrimental effects are rare unless cleaning is continued for an excessive length of time.

INTRODUCTION

IN ORDER to study successfully both microfossils and macrofossils, some cleaning usually is necessary. This cleaning is important for macrofossils especially where the study of microscopic details is necessary in order to make accurate identifications. For example, it is important to determine the plate and pore arrangement of many echinoids to identify them correctly and to determine their stratigraphic significance. For bryozoans, the shape of zooecial apertures and the shape and arrangement of nodes are similarly significant. Microfossils also are often difficult to study because many specimens have marly or clayey fragments clinging to them, and individual cleaning generally is tedious or impossible because of their small size and fragile nature. Obscured foraminiferal apertures and ostracode hinge structures, for example, may prevent identification.

Various cleaning techniques are commonly employed for both microfossils and macrofossils, but all have certain limitations. For many specimens, the boiling and flushing of residues or the scrubbing of specimens is not adequate. Several other techniques, such as the use of solid potassium hydroxide (Bassler, 1953) and oxalic acid (Rasetti, 1949), have been used with varying degrees of success. The disadvantages of these methods are that they involve chemical reactions which may alter the outer surface of the specimens even though considerable care is used. Although some samples are improved substantially by the above methods, others show a definite need for a more effective method of cleaning. Accordingly, the technique of ultrasonic cleaning was investigated in order to evaluate its application in paleontology.

Developments in the field of ultrasonics, the science dealing with sound waves having a frequency above the human audible range, have progressed rapidly in recent years, and an ever-increasing number of practical applications are being described. Preliminary studies on the use and effectiveness of a low-frequency type of ultrasonic generator for the cleaning of macrofossils and microfossils indicated, however, the need for further and more thorough investigation to evaluate its potentialities as a useful device in paleontology.

Most of the reported previous work on applications of this treatment to geologic materials has been involved with experiments to shatter rock samples to recover microfossils, to excavate around embedded vertebrate bones, and to clean adhering clay from mineral grains. One report (Biggs, 1957) demonstrates the successful cleaning of silt grains in soil samples by ultrasonic vibrations.

Ultrasonic cleaners are being applied in the field of palynology where they are used to deflocculate spore-pollen residues, to clean samples that are characterized by the presence of debris adhering to individual specimens, and to accelerate the various chemical phases of sample processing.

Ultrasonic generators also have been used rather extensively in industry and medicine. Many manufacturers are using ultrasonic equipment to clean complexly shaped objects, such as components of watches, jewel bearings, lenses, and electronic equipment. Ultrasonic equipment also has been used for emulsification, mixing and blending, homogenization, and degassing. Other applications of ultrasonic vibrations are as a cleaning agent for surgical instruments and as a mechanism for delicate industrial drilling or cutting.

DESCRIPTION OF EQUIPMENT

Ultrasonic cleaning devices consist of a generator, a transducer, and a cleaning receptacle which is filled with a fluid (usually water) during operation. The generator provides electrical energy which is converted by the transducer to mechanical energy in the form of vibrations. High-frequency ultrasonic vibrations are obtained by means of a ceramic transducer; low frequencies, by a magnetostrictive metal transducer. The vibrations produced by the transducer are transmitted to the fluid in the container where the liquid exposed to ultrasonic energy develops zones of compression and rarefaction which disrupt the fluid and produce the effect called "cavitation." Thus, all surfaces in contact with the liquid are vigorously cleaned.

Although a sample may be placed directly into the cleaning receptacle, it is generally more practical to immerse a sample in a liquid-filled beaker which is then placed in the cleaning receptacle. The beakers are easier to handle and clean, thereby reducing the chances for contamination. A wetting agent or detergent may be added to the liquid-filled beaker to accelerate the cleaning process. An abrasive powder (carborundum) was added to some samples to determine if it significantly accelerated and improved the process. This was unsatisfactory because the specimens were severely pitted; perhaps the introduction of a powder having a hardness lower than that of the specimens would be successful.

The selection of equipment which is applicable for a specific purpose is dependent on knowledge of the effects produced by particular frequency ranges and on the degree of diffusion throughout the solution. Several ultrasonic cleaners were tested; of these, a Bendix model UC-4×8-A portable ultrasonic cleaner was selected because of its adaptability to general use and its ease of operation. It consists of two units, one, a generator having a continuous power output of 180 watts and an output frequency of 19,000 to 22,000 cycles per second, and the other, two magnetostrictive transducers combined with a cleaning receptacle of 1¼ quart liquid capacity. Because some of the sound waves were in the human audible range, it was found to be more satisfactory to enclose the transducer unit within a plywood box lined with an accoustical insulator, such as fiber glass. Insofar as has been determined, however, the vibrations have no deleterious effects on operators or nearby equipment.

The advantages of low-frequency portable ultrasonic cleaners as compared with the higher frequency models are that: (1) magnetostrictive transducers require less power and consequently use smaller input equipment; (2) they are safer to operate and do not require stringent safety precautions; (3) continuous operation is possible as there is no danger of overheating the equipment;

EXPLANATION OF PLATE 93

FIGS. *1*—Coral from the Eocene Weches formation of Texas. *1a*, Before ultrasonic treatment; and *1b*, after treatment. Although adhering material was removed, breakage of septa was extensive during the cleaning process; ×2.

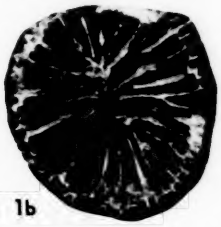
2—Cretaceous orbitoid foraminifer from the Glen Rose formation of Texas. *2a*, Specimen before ultrasonic treatment; and *2b*, after treatment; ×3.

3,4,8,9—Eocene ostracodes from the Lisbon formation of Alabama. *3,8*, Specimens before ultrasonic treatment are covered and are filled by adhering debris; and *4,9*, comparable specimens after treatment; ×60.

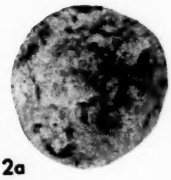
5—Fusulinid from the Permian Waldrip limestone of Texas. *5a*, Before ultrasonic treatment; and *5b*, after treatment; ×5.

6,7—Foraminifers from the Cretaceous Pecan Gap formation of Texas. *6*, Specimen before treatment; and *7*, specimen after treatment; ×60.

10—Pennsylvanian fenestrate bryozoan from the Permian Eiss limestone of Kansas. 10*a*, Before ultrasonic treatment; and *10b*, after treatment; ×9.5.



1b

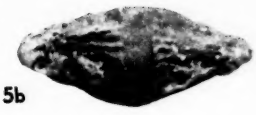


2a

2b

5a

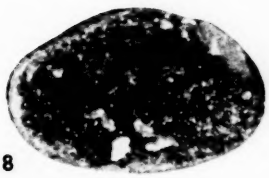
4



5b

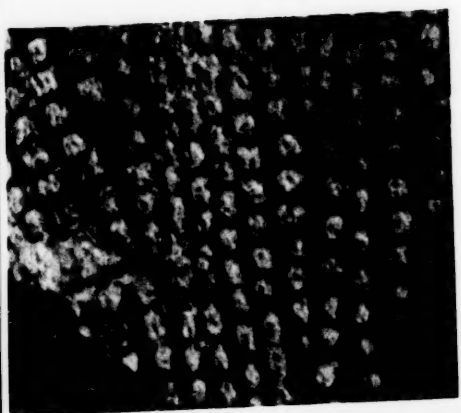
6

7

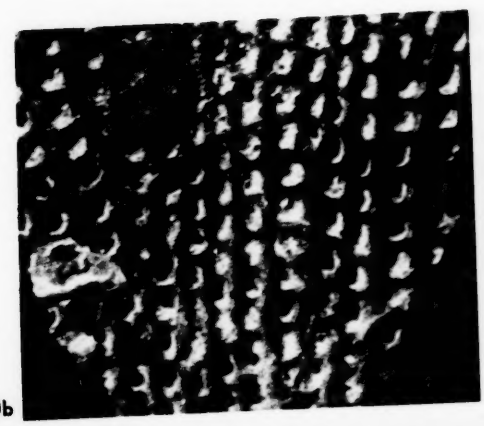


8

9



10a



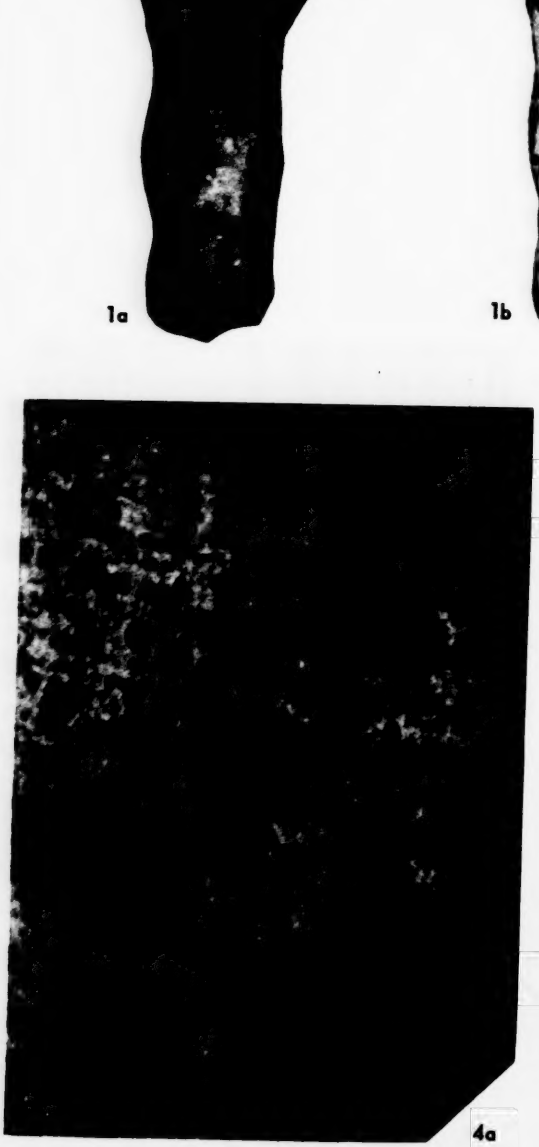
10b

1a

1b

2

3



4a

4b

(4) they are more compact and more easily operated; and (5) they are less expensive.

APPLICATION TO PALEONTOLOGY

In order to evaluate the results of ultrasonic cleaning of fossils, a series of tests were made so that treated and untreated samples could be compared directly. The test specimens included Upper Paleozoic fusulinids, bryozoans, brachiopods, and gastropods; Cretaceous microfossil residues, pelecypods, and echinoids; and Tertiary microfossil residues and corals. All samples were washed with water and dried; then the samples were soaked in Varsol and washed with water until clean. Varsol, a dry-cleaning fluid with a high flash point, was preferred over gasoline (Layne, 1950) because it is safer to use. By employing these techniques, samples were cleaned as thoroughly as was practicable.

The time required for subsequent cleaning of the samples with ultrasonic equipment differed for individual specimens. Fragile specimens (such as globigerinids, poorly cemented arenaceous foraminifers, and thin-shelled ostracodes) were given short ultrasonic treatments (1–2 minutes) to avoid breakage and abrasion. Less delicate specimens (such as most macrofossils and some microfossils, orbitoids, and fusulinids, for example) were treated for 15 minutes or longer with no apparent damage. However, a treatment of 10 or 15 minutes generally cleaned the specimen adequately, making longer treatment superfluous. The length of time required to clean sufficiently an individual specimen or a sample is determined largely by the types of fossils and by the character of the adhering matrix.

An examination of the results showed that cleaning with ultrasonic vibrations was highly successful for many specimens. For the larger fossils, this treatment made the minute details of the surface ornamentation more easily observable (Pl. 93, figs. 2,5; Pl. 94, figs. 1–4), and in the smaller fossils important structures such as ostracode hingelines and foraminiferal apertures were freed of concealing particles (Pl. 93, figs. 3,4,6–9). In most cases, the adhering debris was removed without damage to the specimens. Relatively dense splotches of limestone or limonite on fossils, however, were not removed effectively (Pl. 93, fig. 10; Pl. 94, figs. 2,3), and attempts to dislodge them by long continuous treatment produced detrimental effects, such as abrasion of the surface ornamentation and delicate external structures. It should be noted, moreover, that specimens that are already cracked or in poor condition may be further damaged by ultrasonic treatment (Pl. 93, fig. 1).

It has been observed, also, that the preparation of insoluble residues, particularly from dolomites, may be expedited by combining ultrasonic treatment with the usual acid digestion. Apparently, the chemical reaction is greatly accelerated by the mechanical breakdown caused by the vibrations.

SUMMARY

The cleaning accomplished by ultrasonic vibrations is especially useful for the study of fossils on which small and often-obscured external features are very important. Although the length of time that is desirable for treating samples or specimens is variable, treatment for more than 15 minutes rarely

---

EXPLANATION OF PLATE 94

FIGS. *1*—Permian ramose bryozoan from the Chaffin limestone of Texas. *1a*, Specimen before treatment with ultrasonic vibrations; and *1b*, after treatment; ×9.5.

2,3—Lower Cretaceous echinoids from the Glen Rose formation of Texas. *2*, A specimen after treatment exhibiting cleaned pores of the apical system; and *3*, before ultrasonic treatment showing apical system obscured by clay; ×2.

4—Fenestrate bryozoan from the Permian Eiss formation of Kansas. *4a*, Specimen before treatment showing fenestrules, nodes, and apertures covered by clay; and *4b*, specimen after treatment; ×9.5.

is necessary. The cleaning of fossils by low-frequency ultrasonic vibrations does not always result in perfectly clean specimens, but it is distinctly more advantageous in simplicity, speed, and general effectiveness than other available methods, such as those involving chemical reactions. In addition to aiding in the study of specimens, ultrasonic cleaning tends to improve their general appearance so that more detailed photographs are obtainable.

REFERENCES

BASSLER, R. S., 1953, Bryozoa, Pt. G of Treatise on invertebrate paleontology, R. C. Moore, ed.: Geol. Soc. America and Kansas Univ. Press, 253 p.

BIGGS, D. L., 1957, Cavitation as a means of cleaning silt grains: Iowa Acad. Sci., Proc., v. 64, p. 382–384.

LAYNE, M. M., JR., 1950, A procedure for shale disintegration: Micropaleontologist, v. 4, p. 21.

RASETTI, FRANCO, 1947, Notes on techniques in invertebrate paleontology: Jour. Paleontology, v. 21, p. 396–399.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 731–737, 5 TEXT-FIGS., JULY, 1960

CARBONIFEROUS GONIATITES FROM CABALLEROS CANYON, STATE OF TAMAULIPAS, MEXICO

GROVER E. MURRAY, W. M. FURNISH AND JOSÉ CARRILLO B.
Louisiana State University, Baton Rouge; State University of Iowa, Iowa City; Petróleos Mexicanos, Tampico

ABSTRACT—A few moderately well preserved ammonoid fragments from the Sierra Madre Oriental of southwestern Tamaulipas represent a known Atokan species, *Pseudoparalegoceras amotapense* (Thomas). These are the first such fossils of this age between central Texas, some 500 miles north, and where the species was first described, over 2500 miles southeast in northern Peru. Associated fauna includes another goniatite, *Eoasianites* sp., and a primitive fusulinid, *Fusulinella* sp.

DURING the course of field studies in Caballeros Canyon, a few kilometers northwest of Ciudad Victoria, capital of the State of Tamaulipas (Text-figs. 1–3), the junior author, Ing. José Carrillo B., geologist of Petróleos Mexicanos, collected four goniatites from Paleozoic beds. Because these specimens appear to represent the first known occurrence of Carboniferous cephalopods in Central America, it is considered important to document them.

The goniatites were collected near stream level in dark argillaceous beds which occur south of Rancho El Naranjal, just downstream from the first road crossing on the upstream side of the rancho (Text-fig. 3). The strata in which the goniatites occur are complexly folded and appear to be part of a segment of Paleozoic strata downfaulted into Precambrian-Early Paleozoic (?) schists and gneisses. No other fossils have, at this time, been located in this particular fault segment.

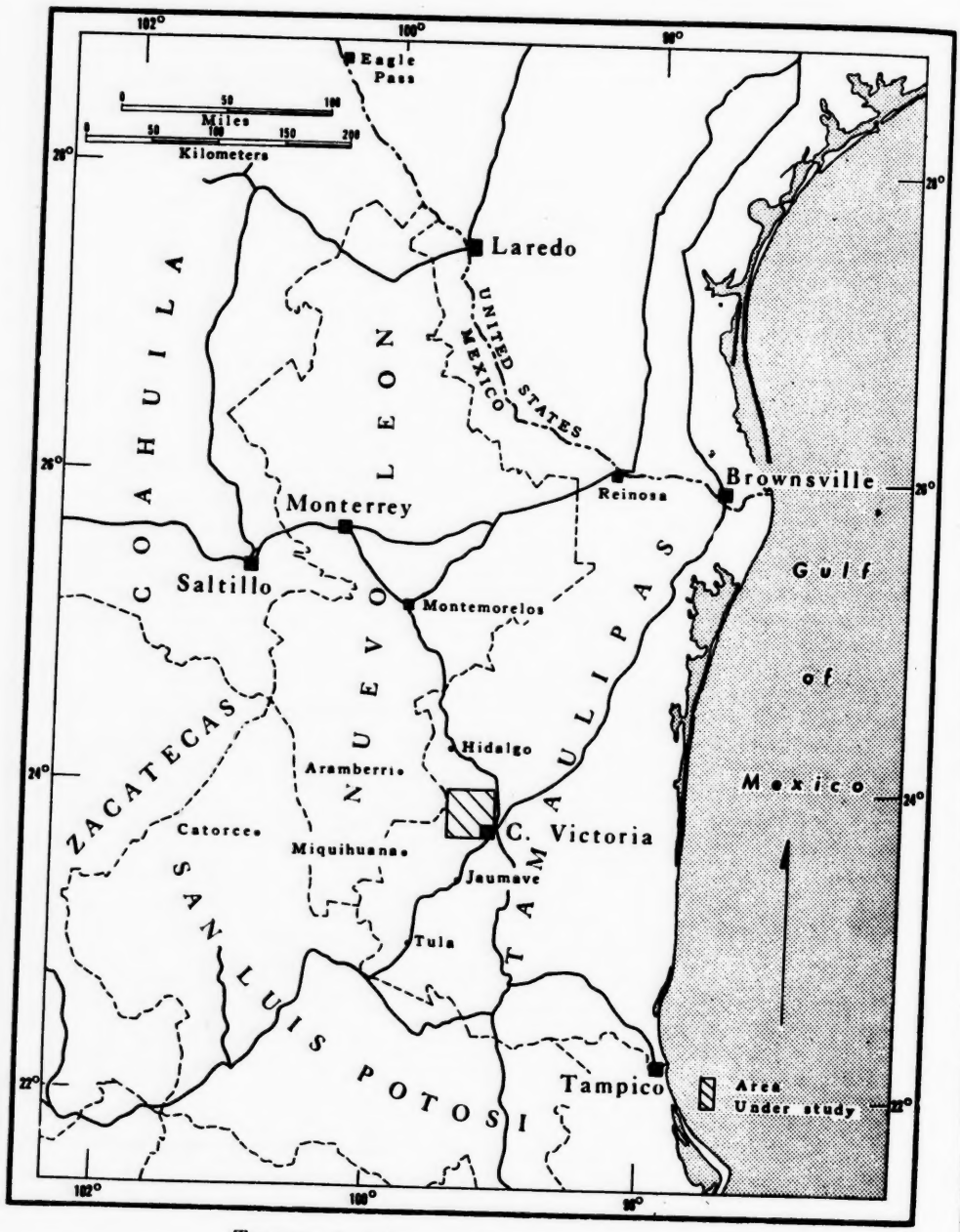
The complex succession of fossiliferous older rocks below Mesozoic strata has long been known to exist in the area north of Ciudad Victoria (Muir, 1936). During the writers' investigations elsewhere in Caballeros Canyon, and in Peregrina Canyon to the south, isolated outcrops of dark argillaceous and calcareous beds yielded other faunas ranging in age from early Mississippian to early Permian. These fossils have been prepared and identified by G. A. Cooper (personal communications to Murray dated 1957 and 1959) and by John W. Skinner (personal communications to Murray, 1959). Collections submitted for study included the goniatites in question, corals, fusulinids, and brachiopods. The exact relationships of these other beds to those containing the cephalopods is presently unknown.

Funds for a field check and for miscellaneous expenses incurred in preparing the paper and illustrations were supplied by a National Science Foundation Research Grant (NSF-G5658) at Louisiana State University (Grover E. Murray, Senior Investigator). Also, we are indebted to A. K. Miller for reading the manuscript critically and to Marvin Klaven for help in preparing illustrations.

Genus PSEUDOPARALEGOCERAS Miller, 1934
Type species: *Gastrioceras russiense* Tzwetaev, 1888

Miller proposed this generic name for a form that has long been regarded as a peculiarity by students of Carboniferous ammonoids. Smith (1903) noted that the Moscovian specimen had the two pairs of lateral lobes, such as existed in *Paralegoceras*, but lacked the additional pair of internal lobes which would serve to distinguish it from the more primitive "*Gastrioceras*." Forms which occur in the Pennsylvanian of northern Peru were referred to this genus originally, and closely similar species have since been recognized in various midcontinent localities. The generic names *Phaneroceras* (Plummer & Scott, 1937) and *Eoparalegoceras* (Delépine, 1941) suggested for related forms are considered to be synonymous with *Pseudoparalegoceras* (Miller & Furnish, 1940, p. 529).

Characteristic features are the thickly discoidal shape and smooth whorls marked



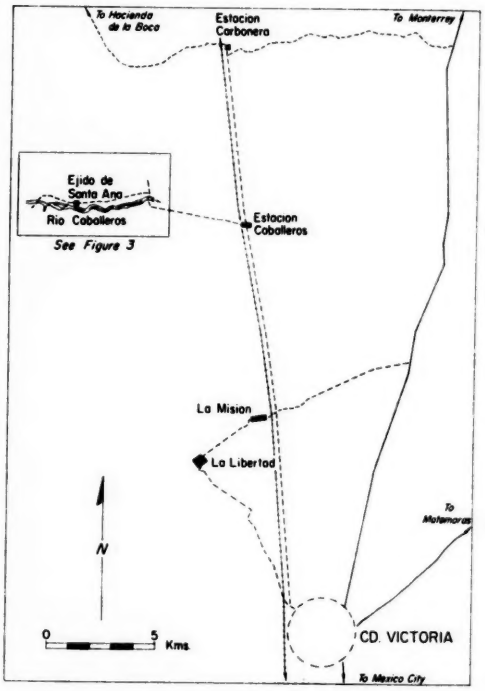
TEXT-FIG. *1*—Index map of northeastern Mexico.

only by transverse constrictions. Growth lines are indistinct and show moderately prominent ventro-lateral salients. The umbilicus exceeds one-third the overall diameter, normally, and approaches one-half the total in immature or extreme cases. A large subdivision of the ventral lobe in the sutures is similar to that in *Paralegoceras;* normally this adventitious portion in *Pseudoparalegoceras* is subequal to the first lat-

eral lobe. The umbilical (second lateral) lobe is situated near the umbilical shoulder; just outside on the flank, or inside on the wall. The exact position appears to be related in part to general shape of the whorl rather than wholly to a basic difference in structure; changes take place in this feature even as a fully mature size is approached.

Representatives of this genus attain a diameter in excess of 100 mm. and are sufficiently common that dozens of individuals can be secured at some localities. In Lower and Middle Pennsylvanian (Morrowan and Atokan) strata, it has been found to be the most common goniatite in several areas.

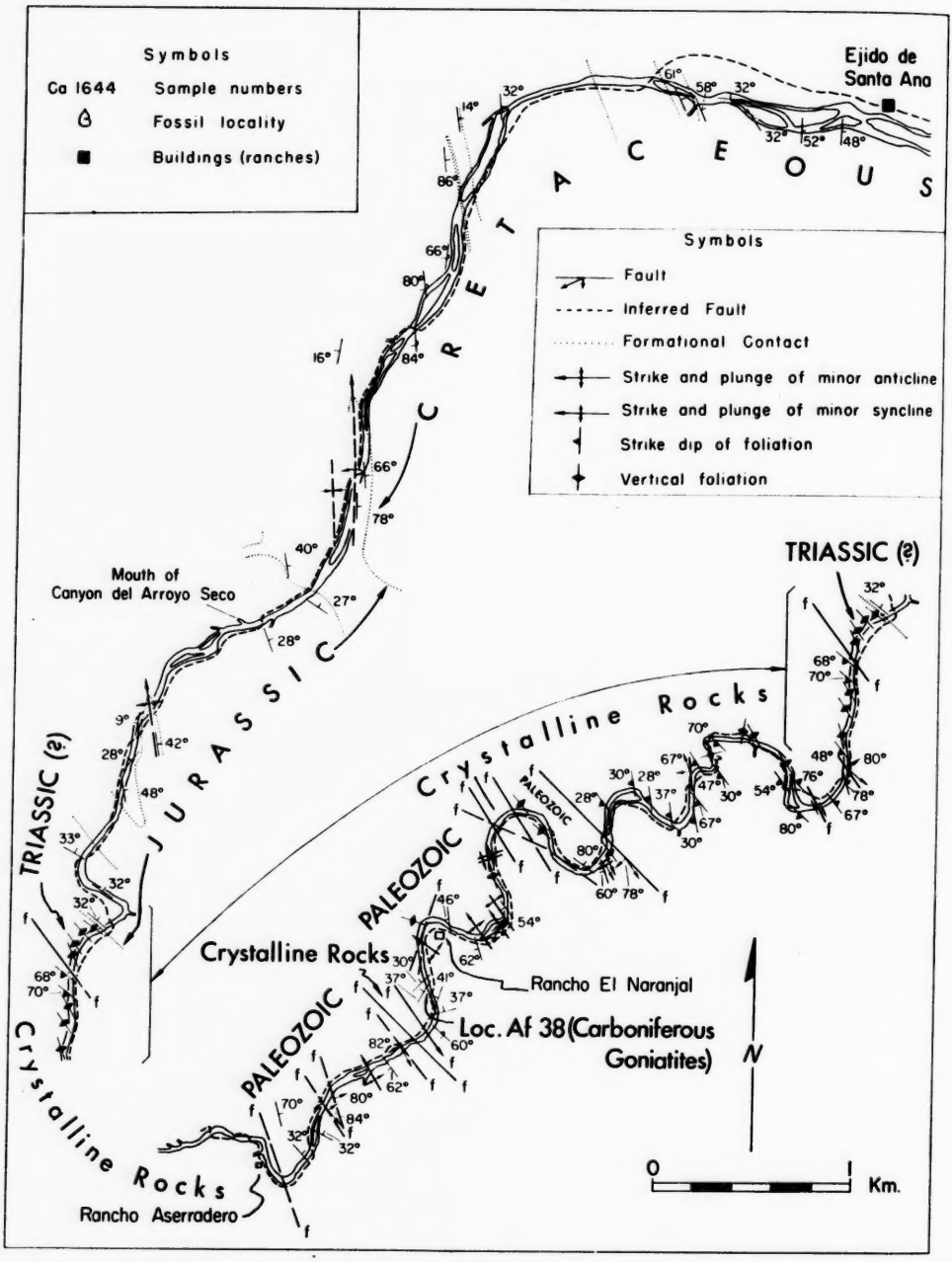
Groups of species have some approximate stratigraphic significance. Those closely related to the Moscovian *Pseudoparalegoceras russiense* (Tzwetaev) include *P. tzwetaevae* Ruzhencev from Middle Carboniferous (Bashkirian) of the Southern Urals, *P. brazoense* Plummer & Scott of Desmoinesian age in central Texas and elsewhere, and *P. bellilineatum* Miller & Furnish from slightly older strata in West Texas. *P. clariondi* (Delépine) from the Upper Westphalian of North Africa is also similar. By contrast, the average Atokan and late Morrowan species is somewhat less specialized in that the umbilical lobe is located on the wall of the umbilicus. *P. compressum* (Hyatt) is a widely umbilicate form; the species *P. amotapense* (Thomas), *P. lenticulare* (Plummer & Scott), and *P. williamsi* Miller & Downs have smaller umbilici but are otherwise similar. The Springeran (Lower Pennsylvanian) goniatite, *Pseudoparalegoceras friscoense* Miller & Owen, lacks characteristic generic features in suture and growth lines and should be placed in some other genus, possibly *Eoasianites*. *Paralegoceras*



TEXT-FIG. 2—Index map showing (1) area of detailed map (Text-fig. 3) and (2) roads north of Ciudad Victoria which permit access to Caballeros Canyon and Canyon del Arroyo Seco.

peruviana Berry [=*Gastrioceras pacificum* Thomas] of Peru has been referred to *Pseudoparalegoceras*, but appears to represent a true *Paralegoceras*, judging by proportions of the external sutures. The septal diagram published by Thomas (1928) may have omitted a shallow internal second lateral lobe. Thomas' figures of *Gastrioceras pacificum* (1928, pl. 12, fig. 2a) as well as those of Chronic (1953, pl. 35, figs. 3,4) show that reticulate shell sculpture, such as

	Diam. mm.	*Umb. %*	*Occurrence*
A. Umbilical lobe of suture on umbilical wall.			
1. *P. amotapense* (Thomas)	90	35–40	Atokan
2. *P. compressum* (Hyatt)	120	45–50	Atokan
3. *P. kesslerense* (Mather)	25	40	Morrowan
4. *P. lenticulare* (Plummer & Scott)	25	30–35	Atokan
5. *P. williamsi* Miller & Downs	100	40	Morrowan-Atokan
B. Umbilical lobe outside umbilicus.			
6. *P. bellilineatum* Miller & Furnish	65	—	Atokan
7. *P. brazoense* Plummer & Scott	60	40	Desmoinesian
8. *P. clariondi* (Delépine)	75	35	Upper Westphalian
9. *P. russiense* (Tzwetaev)	70	40	Moscovian
10. *P. tzwetaevae* Ruzhencev	120	45–50	Bashkirian



TEXT-FIG. 3—Detailed map showing geology along Rio Caballeros and south fork of same river upstream from Ejido de Santa Ana. Plane-table survey and geology by José Carrillo Bravo.

occurs in *Paralegoceras*, is characteristic of this species.

Within the genus *Pseudoparalegoceras* there are two indistinct groups of species. Characteristics appear to be moderately stable, but can be determined with a degree of certainty only in well preserved phragmocones with a diameter of some 75 mm. or more. Although representatives of the two groups have been found associated, there is a tendency for the second group to occur in younger beds.

PSEUDOPARALEGOCERAS AMOTAPENSE (Thomas)

Text-figs. 4,5

Gastrioceras amotapense THOMAS, 1928, Geol. Mag., v. 65, p. 293–295, pl. 10, figs. 6, 6a, pl. 11, fig. 1, pl. 12, fig. 1.

Phaneroceras amotapense PLUMMER & SCOTT, 1937, Texas Univ. Bull. 3701, p. 191; MILLER & MOORE, 1938, Jour. Paleontology, v. 12, p. 351.

Pseudoparalegoceras amotapense MILLER & DOWNS, 1948, Jour. Paleontology, v. 22, p. 678; TERMIER & TERMIER, 1952, Annales Paléontologie, t. 38, p. 13.

Pseudoparalegoceras peruviana CHRONIC, 1953 [part], Geol. Soc. America, Mem. 58, p. 163–164, pl. 35, figs. 1a,1b.

The occurrence of this species in Tamaulipas is based on three specimens: two of these are fragments representing conchs 25–30 mm. in diameter, and the third is of less than 10 mm. diameter. Nature of their preservation is not sufficient to reveal all characters. Nevertheless, the entire external suture, as well as the shape of the whorls, can be seen clearly.

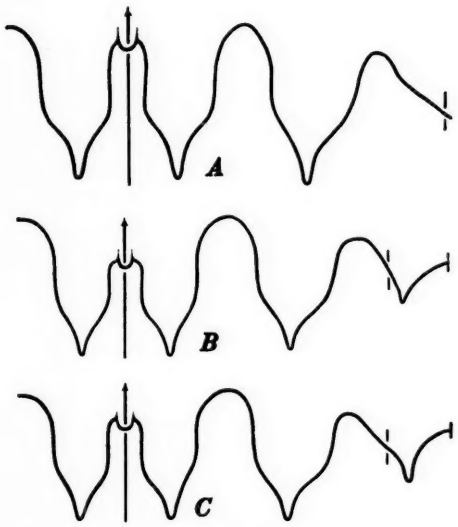
Measurements, in part reconstructed:

Diameter	Height	Width	Umbilicus
29	12	14	12
26	10½	11	9½
8	3	6	3

Although the specimens show some distortion, it is believed most dimensions are reliable within less than a millimeter, or 5 percent.

In the two larger individuals under consideration, the suture shows adventitious subdivisions of the ventral lobe to be nearly as large as the first lateral, in a proportion of about 7:10. This relationship is about the same as other representatives of the genus at equivalent diameters.

Both the lateral lobe and the subdivisions

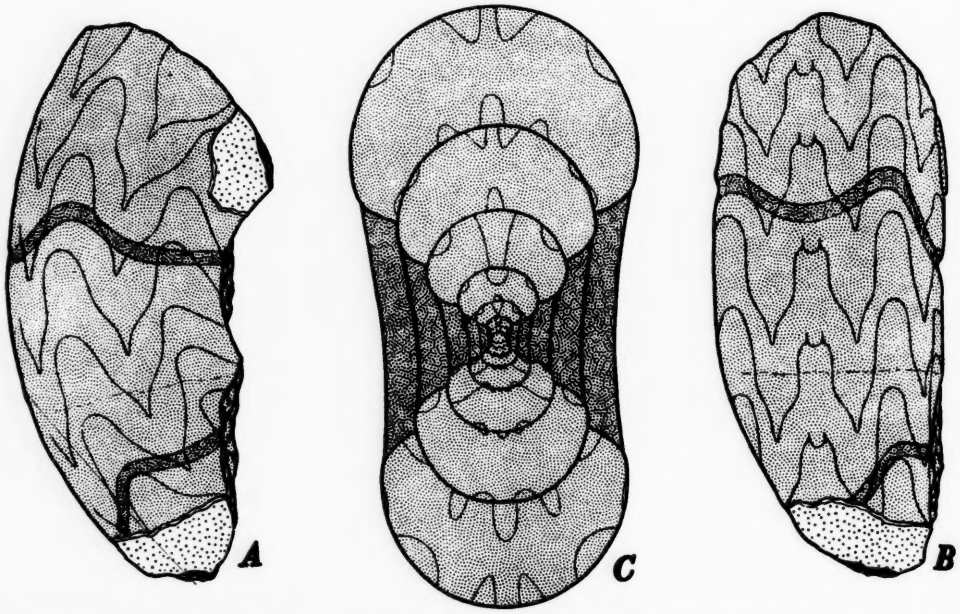


TEXT-FIG. 4—External sutures of *Pseudoparalegoceras*.
A,B. *P. amotapense* (Thomas). A, from the Amotape Mountains of Peru, based on the holotype at a diameter of 70 mm., ×1¼; after Thomas. B, from Pennsylvanian strata in southwestern Tamaulipas (State Univ. Iowa 8139) at a diameter of about 28 mm., ×3. C. *P. lenticulare* (Plummer & Scott) from the Barnett Hill Member of the Atoka Formation near Clarita, Oklahoma (State Univ. Iowa 9776) at about 25 mm. diameter, ×3½.

of the ventral lobe are attenuate. The secondary ventral saddle portrays a marginal siphuncle which is strongly prochoanitic. The height of this saddle is nearly as great as that of the narrowly rounded first lateral saddle and fully as high as the second lateral saddle. The umbilical lobe is located on the umbilical wall.

The immature stage of the suture visible on the small third specimen shows major differences in proportion and other details. At this stage, the prongs of the ventral lobe approximate 40 percent of the lateral in size. The relative height and depth of the sutural elements is also much less.

Portions of the test are retained and other parts have been removed in preparing the specimens for study. The shell is crystalline and shows little detail, but no pronounced surface sculpture is apparent. Constrictions on the molds existed primarily as internal thickenings of the shell; there are 4 or 5 per volution at 25–30 mm. diameter. These bi-



TEXT-FIG. 5—Diagrammatic figures of Atokan *Pseudoparalegoceras*, ×3½. A,B. Outline views of *P. amotapense* (Thomas) from Pennsylvanian strata in southwestern Tamaulipas (State Univ. Iowa 8139). C. Cross section of *P. compressum* (Hyatt) from the lower Atoka Formation at railroad tunnel, Winslow, Arkansas (State Univ. Iowa 9775).

convex constrictions presumably correspond to growth lamellae in form; relatively prominent ventro-lateral salients with adjacent sinuses are characteristic of the genus.

Remarks.—Comparisons with Thomas' descriptions and illustrations of *Pseudoparalogoceras amotapense* reveal no significant differences. This close relationship is equally true for some Atoka material of Oklahoma and Arkansas that has been identified as *P. williamsi* Miller & Downs. An umbilical proportion of some 40 percent distinguishes the species from Smithwick forms referred to *P. compressum* (Hyatt), in which the umbilicus is between 45 and 50 percent at comparable size. *P. lenticulare* (Plummer & Scott) from West Texas has a smaller umbilicus, 30–35 percent. It should be emphasized, however, that the several specific types now recognized by these proportions may occur in the same beds and are gradational to a certain extent.

Associated lithology.—The specimens available for study are all only moderately preserved as crystalline internal molds. There is some fragmentation and partial displacement of shell material, apparently related to diagenesis. Rock and specimens show calcite veinlets. The matrix is a calcarenite so sandy that a considerable proportion consists of coarse angular quartz fragments. Other fossils include crinoidal debris, bryozoan fragments, and small fusulinids. The fusulinids, moderately well preserved and common, appear to be referable to *Fusulinella*. M. L. Thompson (personal communication, 1959) advises that the species is closely similar to *F. acuminata* Thompson, known from strata in South Dakota and in west Texas and New Mexico.

Type specimens.—State University of Iowa collections, catalogue no. 8139.

EOASIANITES sp.

One poorly preserved fragment of several whorls attains a diameter of some 15 mm. The corresponding measurements are 12 mm. width, 5 mm. height, and 8 mm. umbilicus. This individual differs from the associated specimens of *Pseudoparalegoceras amotapense* in several respects.

Surface features cannot be discerned. The

simple gastrioceratid suture has relatively small subdivisions of the ventral lobe, only about 35 percent the size of the lateral. Although immature, the wide umbilicus and low broad whorls are sufficient to classify such a form with this lobe proportion and only eight basic elements in the suture.

A polished section across the whorls shows that there are at least seven volutions represented. Also, it is apparent that the conch was so fractured during preservation that detailed measurements of the volutions cannot be regarded as reliable.

This usage of the genus *Eoasianites* is not in as restricted a sense as that employed by Ruzhencev (*e.g.*, 1950, p. 129–139). According to his interpretation, a whorl-width-to-diameter ratio of 80 percent, plus the lack of conspicuous umbilical nodes, would place this specimen in the group of species designated as *Glaphyrites*. Irrespective of the importance attached to these differences, the overall group here called *Eoasianites* is a common element at many localities in Pennsylvanian and Lower Permian rocks. Variations in shell proportions do not appear to be of stratigraphic significance, for the two groups are found associated.

Similar representatives of *Eoasianites* occur in the midcontinent area and other parts of the world. For example, *Gastrioceras? parinasense* Thomas of Peru and *Eoparalegoceras inflatum* Delépine from North Africa are both probably congeneric with this form from Tamaulipas.

Repository.—State University of Iowa collections, no. 8043.

REFERENCES

CHRONIC, JOHN, 1953, Upper Paleozoic of Peru, Part 2, Invertebrate Paleontology (excepting fusulinids and corals): Geol. Soc. America, Mem. 58, p. 43–165, pls. 5–35.

DELÉPINE, GASTON, 1941, Les goniatites du Carbonifère du Maroc et des confins Algéro-Morocains du Sud (Dinantien-Westphalien): Protect. État Fr. Maroc, Direction gén. Trav. publ., Div. Mines et géol., Serv. Géol., Notes et Mém., no. 56, 111 p., 8 pls.

——, 1951, Description d'une goniatite nouvelle du Westphalien du Sud Oranais, *Eoparalegoceras inflatum:* Soc. Géol. Nord. Annales, t. 70, p. 179–184, pl. 6.

DÍAZ, TEODORO & HUMPHREY, W. E., 1956, Geologia entre Reynosa, Tamaulipas, y Mexico, D. F.; Itinerario Ciudad Victoria-Canon de Peregrina: 20th Internat. Geol. Congress, Regional Monographs, Excursion A-14, p. 63–68.

LIBROVITCH, L. S., 1947, Goniatite faunas of the Carboniferous of the U.S.S.R. and their significance in the stratigraphy of these deposits: Moskovskoe Obshchestvo Ispytatelei, Prirody, Bull., Otdel Geol., tom 22, nr. 5, p. 51–68 [in Russian].

MILLER, A. K., 1934, *Pseudoparalegoceras*, a new genus of Carboniferous ammonoids: Jour. Paleontology, v. 8, p. 18–20, pl. 2.

—— & DOWNS, R. H., 1948, A cephalopod fauna from the type section of the Pennsylvanian "Winslow Formation" of Arkansas: *ibid.*, v. 22, p. 672–680, pls. 101–103.

—— & FURNISH, W. M., 1940, Studies of Carboniferous ammonoids, Part 5, The Pennsylvanian ammonoid genus *Paralegoceras* and related forms: *ibid.*, v. 14, p. 521–533, pls. 62,63.

—— & ——, 1958, Middle Pennsylvanian Schistoceratidae (Ammonoidea): *ibid.*, v. 32, p. 253–268, pls. 33,34.

MIXON, R. B., MURRAY, G. E. & DÍAZ G., TEODORO, 1959, Age and correlation of Huizachal (Mesozoic), State of Tamaulipas, Mexico: Amer. Assoc. Petroleum Geologists, Bull., v. 43, p. 757–771.

MUIR, J. M., 1936, Geology of the Tampico Region, Mexico: Amer. Assoc. Petroleum Geologists, Spec. Publ., 280 p., 15 pls.

PLUMMER, F. B. & SCOTT, GAYLE, 1938, The geology of Texas, Volume III; Part 1, Upper Paleozoic ammonites in Texas: Texas Univ. Bull. 3701, p. 1–516, pls. 1–41.

RUZHENCEV, V. E., 1950, Upper Carboniferous ammonites of the Urals: Akad. Nauk SSSR, Tr., tom 29, 223 p., 15 pls. [in Russian].

——, 1951, Discovery of the genus *Pseudoparalegoceras* in the Aktiubinsk District, Kazakh S.S.R.: Akad. Nauk, SSSR, Doklady, tom 78, p. 769–772 [in Russian].

——, 1958, Namurian Stage of marine stratigraphic facies: Moskovskoe Obshchestvo Ispytatelei, Prirody, Bull., Otdel Geol., tom 33, nr. 5, p. 23–35 [in Russian].

SMITH, J. P., 1903, The Carboniferous ammonoids of America: U. S. Geol. Survey, Mon. 42, 211 p., 29 pls.

TERMIER, HENRI & GENEVIÈVE, 1950, Invertébrés de l'Ère primaire; Fascicule 3, Mollusques: Paléont. Marocaine, t. 2, p. 1–238, pls. 123–183.

——, 1952, Les goniatites du Namuro-Moscovien (Pennsylvanien) de Kenadza (Sud-Oranais, Algérie): Annales Paléontologie, t. 38, p. 1–34.

THOMAS, H. D., 1928, An Upper Carboniferous fauna from the Amotape Mountains, northwestern Peru: Geol. Mag., v. 65, p. 146–152, 215–234, 289–301, pls. 5–8 10–12.

THOMPSON, M. L., 1948, Studies of American fusulinids: Univ. Kansas, Paleont. Contr., Protozoa, Art. 1, 184 p., 38 pls.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 738–743, 2 TEXT-FIGS., JULY, 1960

MAGNETIC SEPARATION OF CONODONTS

VERNE E. DOW
State University of Iowa, Iowa City

ABSTRACT—A rapid convenient means of conodont concentration with the Frantz Isodynamic Magnetic Separator is described. Results with various types of residues are discussed and factors established for use of the instrument for this purpose.

INTRODUCTION AND ACKNOWLEDGMENT

ONE of the major problems in the study of conodonts is the laborious task of securing them from residue. In some cases the fossils may be sufficiently abundant and the selection easy. Heavy liquids provide a means of concentration. In most cases, however, the number of conodonts in proportion to the amount of final residue is small, and it becomes a long and tiring task to pick out the fossils. Dolomites, in particular, are difficult to work with because there is such a small amount of acid soluble material removed in the initial preparation of the sample, and the specific gravity is nearly the same as that for conodonts.

Rosenblum (1958) noted that apatite had been found to be weakly magnetic and could be concentrated by using the Frantz Isodynamic Magnetic Separator. As conodonts are composed of the mineral apatite (Rhodes, 1954; Rhodes & Wingard, 1957) it seemed quite logical that they could be separated magnetically.

By using the Frantz Separator, the author processed a number of samples of varied lithology. A separation procedure has been developed which should be applicable to all types of conodont-bearing residue.

During the course of this study it was found that spores and spore cases could also be separated, but no definite method for use of the instrument has been formulated.

The writer wishes to thank W. M. Furnish, R. A. Hoppin, and B. F. Glenister for their assistance in the final preparation of this paper. Also, the writer is grateful to R. B. Campbell of the Iowa Geological Survey for his help in preparation of some of the control samples used in the study.

PRINCIPLES

The basic principle behind this method is the fact that all substances show varying response to magnetic fields. The type of magnetism exhibited by any particular material depends on its permeability (magnetic permeability = ratio of magnetic induction to the magnetizing force), which in most cases differs only slightly from the value 1. On the basis of permeability, three major groups have been recognized generally: ferromagnetics, with large permeabilities; diamagnetics, with permeabilities slightly less than 1; and paramagnetics, with permeabilities slightly greater than 1. Ferromagnetic and paramagnetic materials when placed in a magnetic field will experience a force which will cause them to move from the weaker to the stronger part of the field. Diamagnetic minerals when placed in a magnetic field will act in an opposite manner. That is, they will tend to move from the stronger to the weaker part of the field.

A variety of minerals occurs in sedimentary rocks, and each has its range of magnetic susceptibility. In practice the problem of working out a separation involves the determination of this range of susceptibility for the principal constituents of any particular residue.

The instrument used in this study consists of the following:

1. A powerful electromagnet with a rheostat for adjusting the field strength;
2. A vibrating chute of nonmagnetic material through which the minerals to be separated are moved;
3. Adjustable vibrator to control vibration chute;
4. A feed funnel with adjustable rate;
5. Two nonmagnetic collecting cans;

6. A precise calibration for adjustment of forward and side inclinations of the magnet.

Samples fed onto the chute are acted upon by the magnetic field, which is strongest on the left side of the chute and weakest on the right side. As the particles move down slope, they are forced to take paths depending on their susceptibility. A "splitter" at the center of the chute guides the separated materials into the outer and inner collectors. The outer, left side, of the two collectors receives the more magnetic fraction of any particular run.

GENERAL METHOD

Reduce the residue as far as possible with standard treatment of acid solution and "washing" techniques. Boiling and washing with a chemical deflocculant, such as sal soda, removes much of the troublesome fine clay that may otherwise be present. Dust-size particles impair a good separation. The sample should be carefully screened, because uniform particle size yields the best results.

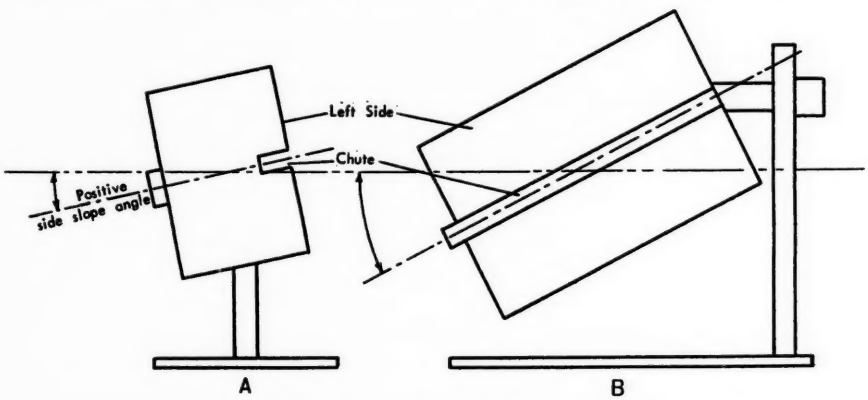
After the residue has been washed and dried, it should be examined with a microscope to determine the dominant mineralogy. This determines the various settings for the first run through the separator.

After the sample has been passed through the separator, the magnetic and nonmagnetic fractions should be examined with a microscope to check how effective the separation has been. In many cases, an initial pass will remove the majority of the more magnetic material free of conodonts. If conodonts do occur on the magnetic side on the first run, probably the material was being fed too rapidly or the forward slope too steep (Text-fig. 1). If the current to the coils is lowered or shut off before the entire run is completed, conodonts will also accumulate in the magnetic side on the first run. Also, magnetic materials which should be removed in the first run may be incorporated in the nonmagnetic portion. The main reasons for this type of contamination are too high amperage and too rapid feeding. High amperage may attract an aggregate of highly magnetic materials clogging the chute on the magnetic side, causing magnetics and nonmagnetics to go down the nonmagnetic slot together.

To further concentrate the conodonts after the initial run, the portion of the sample in the nonmagnetic side is passed through the instrument at prescribed settings, depending on the type of mineralogy. Some samples need to be passed through only once, while others may take several passes. The number of runs depends only on the lithology of the residue and the degree of separation desired by the operator. Examples of several types of residues are discussed in the section dealing with results.

Many times a fine powder accumulates with the separated fractions. This may be removed by dry screening.

It should be noted here that discussion of magnetic fractions of the separation refers to material which is removed at any particular setting and moves to the outer (left) slot



TEXT-FIG. *1*—Diagrammatic sketch showing positive side slope A, and forward slope B.

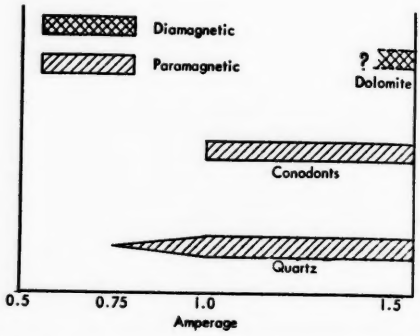
of the instrument. In general there will be a magnetic and a nonmagnetic fraction for each setting of the instrument. In the early stages of the separation, the nonmagnetic fractions may contain paramagnetics and diamagnetics but probably no ferromagnetics. As the degree of separation is increased, the fraction referred to as nonmagnetic is primarily, if not completely, diamagnetic.

After running a number of samples, it became apparent that most of the conodonts were concentrated in the nonmagnetic side after one or two runs. Quartz and dolomite were the most common minerals present in the conodont-bearing portion, with minor amounts of other minerals. In some cases, conodonts are so abundant that no further reduction is necessary after the first run.

DETERMINATION OF RANGE OF SUSCEPTIBILITY

In order to determine the amperage and slope needed to give optimum separation of conodonts, approximately 0.2 grams of conodonts were first concentrated from a Lime Creek shale sample (Upper Devonian of Iowa). After a number of runs it was determined that nearly all the conodonts came out as paramagnetics in one pass with a forward slope of 10°, a side slope of −2°, an amperage setting of 1.5, a slow feed, and a vibrator setting of 2.5. However, conodonts appeared on the nonmagnetic side at an amperage of 1.0 (Text-fig. 2).

Dolomite was found to be held completely on the magnetic side at the same setting as that used for maximum conodont separation. This relationship is quite reasonable, for in petrographic examination of dolomites there seems to be a characteristic banding of iron in the dolomite rhombohedrons. Some dolomites will contain more and some less iron than others. Some have greater or less magnetic susceptibility than others. However, the settings mentioned above seem to serve quite well for all the samples which were encountered in this study. If the separator is placed in a cool place, or if a fan is used to cool the coils, a higher amperage will be developed for a longer time. A small transformer can be secured to boost the output of the instrument. Maximum available amperage should be used when separating dolomite residues.



TEXT-FIG. 2—Range of magnetic susceptibility of quartz, dolomite, and conodonts with forward slope 10° side slope −2°, 3.0 vibrator and slow feed.

Quartz overlaps the lower range of conodont separation. With a 10° forward slope, −2° side slope, slow feed, and 2.5 vibrator setting conodonts will start to move to the nonmagnetic side at 1.0 ampere. Quartz begins to move to this side at 0.75 ampere, but it does not move in a significant amount until 0.9 ampere is reached. At 0.9 ampere most of the quartz moves to the nonmagnetic side. Any increase above 0.9 ampere will cause conodonts to move over with the quartz. Therefore, it is desirable to run the conodont-bearing fraction through more than once, with removal of some quartz with each pass. Another complicating factor of the separation is the presence of limonite on quartz grains. If there is sufficient limonite on the surface of the grains, much of this material can be attracted to the magnetic side by a forward slope of 10°–15°, side slope *positive* 1°–2°, slow feed, maximum amperage, and vibrator setting of 2.5.

RESULTS

1-MS Stratigraphic unit: Lime Creek Shale (Upper Devonian, eastern Iowa)

Lithology of residue: 75–85% limonite, pyrite, 5–10% clear rounded frosted quartz grains; 4–5% dolomite; <5% rock fragments, with a trace of green clay, and moderately abundant conodonts. The weight of the sample was 2.89 grams.

The sample was passed through the sep-

arator at 25° forward slope, 15° side slope, 1.0 ampere, 4.0 vibrator, and slow feed. The result of this run was 2.63 grams of barren material on the magnetic side and 0.26 grams on the nonmagnetic side which contained all the conodonts. The 0.26 gram fraction contained some quartz, dolomite, and other impurities and such a large number of conodonts that further separation would not be necessary. However, the 0.26 grams was passed through again at 10° forward slope, −2° side slope, maximum amperage (1.5+), 3.5 vibration setting, and a slow feed to remove the dolomite. The results of this run in one pass were 0.20 grams magnetic and 0.06 grams in the nonmagnetic side. The 0.06 grams was 95%+ conodonts. There were some conodonts in the 0.20 gram fraction, but these were separated by repeating the run twice at the same setting.

2-MS Stratigraphic unit: Des Moines Shale (Middle Pennsylvanian, south central Iowa)

Lithology of residue: 45–50% dark pyrite rich shale particles; 5–10% pyrite and limonite; 45–50% quartz, clear and iron stained; scattered conodonts. Weight of sample 12.98 grams.

Sample was passed through the separator at 25° forward slope, 10° side slope, 1.3 ampere, 4.0 vibrator setting, and fairly fast feed. Amperage was reduced to 1.0 because the magnetic material kept clogging the chute. The result of this run was 7.66 grams of barren material on the magnetic side and 5.32 grams on the nonmagnetic side containing all the conodonts. The nonmagnetic fraction was mostly clear and iron-stained quartz. The 5.32 gram fraction was passed through the separator at 25° forward slope, 5° side slope, 1.35 ampere, 2.5 vibrator, and slow feed to remove the last traces of "highly" magnetic material. The result of this run was 0.44 grams magnetic material, which contained a few iron-stained conodonts, but mostly iron-stained quartz. The remaining 4.89 grams contained conodonts, and clear and lightly stained quartz. The 4.89 grams were passed through the separator twice at 10° forward slope, −2° side slope, 0.9 ampere, 3.0 vibrator, and slow feed. The result of these runs were 4.67 grams on the magnetic side with all the conodonts, and 0.22 grams of clear quartz on the nonmagnetic side.

The reason conodonts did not separate very well from the quartz in the last stage seems to be due to the iron on the surface of the sand grains which altered their diamagnetic properties.

6-MS Stratigraphic unit: Winterset Formation (Upper Pennsylvanian, western Iowa)

Lithology of residue: 90–95% light green clay-shale, 5–10% limonitic material, <5% quartz, trace of dolomite, and rock fragments. Weight of sample 6.63 grams.

This sample was passed through the separator twice at 20° forward slope, 10° side slope, 1.3 ampere, 3.0 vibrator, and medium fast feed. The result was 5.63 grams barren material on the magnetic side and 1.00 grams containing all the conodonts on the nonmagnetic side. The magnetic fraction contained the green clay shale and limonitic material, this is presumably because the green shale contained considerable iron in the reduced state. The nonmagnetic side contained conodonts, quartz, dolomite and some green clay shale. The remaining shale was removed by running the sample through at 15° forward slope, 2° side slope, maximum amperage (1.5+), 3.0 vibrator and medium fast feed. After removal of the shale there remained 0.31 grams containing conodonts, quartz, and dolomite. A final pass of 10° forward slope, −2° side slope, 1.5 ampere, 3.0 vibrator, and slow feed left 0.18 grams of material with quartz and conodonts. No attempts were made to separate the quartz from the conodonts in this last stage.

7-MS Stratigraphic unit: Pella Limestone (Upper Mississippian, south central Iowa)

Lithology of the residue: 60–65% limonitic material, 30–35% dolomite, and undigested fossils, presumably dolomitic, 4–5% quartz, a few conodonts. Weight of the sample 5.35 grams.

The sample was passed through twice at 25° forward slope, 10° side slope, 1.0 ampere, 3.0 vibrator, and medium fast feed. The result was 3.15 grams of barren material on the magnetic side, and 2.20 grams on the nonmagnetic containing all the conodonts. The 2.20 gram fraction was put through

again at 25° forward slope, 2° side slope, 1.35 ampere, 2.5 vibrator, and slow feed, and this removed 0.56 grams of barren material on the magnetic side. The 1.54 grams left from the third pass consisted mainly of dolomite, quartz, undigested ostracod shells, and conodonts. A final run of 10° forward slope, −2° side slope, maximum amperage (1.5+), 2.5 vibrator, and slow feed separated 0.75 grams of dolomite on the magnetic side from 0.79 grams of quartz, shell fragments, and conodonts on the nonmagnetic side.

9-MS Stratigraphic unit: Lime Creek Formation (Upper Devonian, eastern Iowa)

Lithology of residue: Almost 100% flattened spore cases, some spores, small amounts of pyrite, dolomite, and rock fragments. Conodonts present but not abundant. Weight of residue 1.37 grams.

This sample was run through the separator three times to remove the spore material. The first run was at 20° forward slope, 10° side slope, 1.1 ampere, 3.0 vibrator, and medium fast feed. The second at 20° forward slope, 5° side slope, 1.3 ampere, 3.0 vibrator, and medium slow feed. The third run was at 15° forward slope, 2° side slope, 1.35 ampere, 3.0 vibrator, and medium slow feed. The spores came out on the magnetic side of the separator in the following amounts: first run, 0.88 grams; second run, 0.17 grams; third run, 0.07 grams. After three runs, all the conodonts were concentrated in 0.23 grams along with dolomite and quartz. One final separation at 10° forward slope, −2° side slope, 1.5 ampere, 2.5 vibrator, and slow feed removed 0.21 grams of dolomite and very fine pyrite on the magnetic side leaving the conodonts concentrated in the remaining 0.02 grams. There were a few conodonts remaining in the magnetic side, but one or two runs at the same setting would remove these if desirable.

12-MS Stratigraphic unit: ? (Upper Devonian dolomite, Nevada)

Lithology of residue: nearly 100% very light brown dolomite rhombohedrons with scarce conodonts. Weight of this sample was 2.68 grams.

This residue was passed through the separator only once at 10° forward slope, −2° side slope, maximum amperage (1.5+), 2.5 vibrator, and very slow feed. The magnetic fraction contained 2.63 grams of material and after careful examination only three fragments of conodonts could be found. The nonmagnetic side contained 0.05 grams and had a fairly large number of conodonts plus some dolomite rhombs.

DISCUSSION AND CONCLUSIONS

After processing a number of samples of different lithologies, certain conclusions can be drawn as to the type of instrument settings which may be used for conodont separation. The specific cases discussed are regarded as representative.

Residue which contains appreciable amounts of limonite should be run through the separator at forward slopes of 20–25°, side slopes 10–15°, 1.0 to 1.3 ampere, 4.0 vibrator and medium fast feed. In cases where there are extremely large percentages of limonite it is best to run the sample one time at 1.0 ampere and then rerun the nonmagnetic portion at 1.3 ampere. This prevents aggregation and clogging the chute during separation. The above separation results in a barren magnetic portion and a concentration of conodonts in the nonmagnetic side. The concentration of conodonts in the nonmagnetic side determines whether further separation is desired. Since most of the nonmagnetic residues at this stage contain nearly the same types of minerals (quartz and dolomite), the separation of this fraction will be discussed further.

If the residue is mainly clay shale in shades of red or green, the initial run should be from 10–15° forward slope and a 5–15° side slope, with a maximum amperage, medium fast feed, and vibrator at about 4.0. If the sample is run through at one of the higher side slopes 10–15° and some of the material goes to the nonmagnetic side, that portion should be rerun at a lower side slope setting, such as 2–5°.

After the initial one or two passes, whichever gives the best separation, the nonmagnetic fraction should be passed through at a different setting to further concentrate the conodonts. If the nonmagnetic fraction is principally dolomite, use the following settings: 10° forward slope, −2° side slope, maximum amperage, 2.5–3.0 vibrator, and slow feed. These settings will separate dolomite (paramagnetic) from conodonts, and

quartz which are diamagnetic. If the residue is principally clear quartz, use the same setting as for dolomite except for the amperage which should be 0.9.

Residue which is principally quartz is the most difficult to separate because of varying amounts of iron-oxide on the grains, causing a change in diamagnetic properties of the quartz. However, if the quartz is free or nearly free from iron, it can be separated from conodonts, with the following settings: forward slope 10°, side slope −2°, 0.9 ampere, 2.5 to 3.0 vibrator, and slow feed. Conodonts will remain on the magnetic side, as they are not as diamagnetic as quartz. When very small amounts of iron stain are present on the surface of the quartz, it is often necessary to pass the magnetic portion through several times to insure separation. In many cases, it is advantageous to pass the sample through the separator at 25° forward slope, 10° side slope, maximum amperage, 4.0 vibrator, and fast feed to remove the more magnetic material.

Samples which are mainly dolomite should be passed through the separator at 10° forward slope, −2° side slope, vibrator 2.5 to 3.0, maximum amperage, and very slow feed. Since most dolomites contain a large volume of residue in proportion to the number of conodonts, it is often desirable to rerun both magnetic and nonmagnetic fractions.

Only a few of the many possible residues have been studied by the author, and it should be kept in mind that the settings described above may need to be modified somewhat for various types of lithologies in the initial stages of separation. However, those settings described for dolomite, quartz, and conodont separations should remain fairly constant.

In modifying the settings for the initial separation, it should be kept in mind that by decreasing the forward slope, rate of feed, and vibrator settings, you are increasing the amount of time the magnetic field will act on a particle. The vibrator should be set so the particles bounce down the chute. It seems that a better separation can be made if the particles bounce (but not too fast) rather than slide down the chute. Another factor to consider is that as the side slope is decreased the particles with lesser paramagnetism will be attracted to the magnetic side.

REFERENCES

RHODES, F. H. T., 1954, The zoological affinities of the conodonts: Biol. Rev., v. 29, p. 419–452.

—— & WINGARD, P. S., 1957, The structure, chemical composition and affinities of the Neurodontiforms: Jour. Paleontology, v. 31, p. 448–454.

ROSENBLUM, SAM, 1958, Magnetic susceptibilities of minerals in the Frantz Isodynamic Magnetic Separator: Amer. Mineralogist, v. 43, p. 170–173.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 744–755, 2 TEXT-FIGS., JULY, 1960

MAGNESIUM, STRONTIUM, AND ARAGONITE IN THE SHELLS OF CERTAIN LITTORAL GASTROPODS

DAVID KRINSLEY
Queens College, Flushing, New York

ABSTRACT—Strontium, magnesium, and aragonite percentages were examined in modern and fossil shells of *Tegula funebralis*, *Olivella biplicata*, and *Fissurella volcano*. Statistical tests were used to determine whether differences existed between modern and fossil locality means and variances with respect to the three measures listed above. Strontium was relatively stable with time in the shell material examined, while magnesium was mobile; aragonite percentages also appeared to be stable during the time period examined. Magnesium in shell material of the same species at two different locations of the same age reacted differently to post-depositional change.

INTRODUCTION

THE utility of such measures as trace elements, aragonite percentages, oxygen isotope measurements, etc. in paleoenvironmental reconstruction has been investigated recently. Chave (1954, a,b), Lowenstam (1954 a,b) and Odum (1950), among others, have used these measures to study modern and fossil shell material. These investigations have dealt chiefly with a few individuals of many species. The present study is concerned with magnesium, strontium, and aragonite percentages in relatively large samples of shells of three species of gastropods drawn from large portions of their modern geographic ranges and the Pleistocene.

The occurrence of the same species living close together geographically in both Recent and Pleistocene time presents an unparalleled opportunity to study the stability of the aforementioned properties through the time-diagenetic zone (Miller & Olson, 1955). It is necessary to examine the intraspecific variation of these measures in modern animals to gauge the full importance of diagenetic alteration.

Geochemical and mineralogical data on modern and fossil shell material are quite limited, but have recently been supplemented by a number of papers. Boggild (1930) noted the coexistence of calcite and aragonite in shell material in many groups of mollusks. He considered that his analyses were representative of the species investigated and as such assumed that the polymorphic composition was fixed within a species or higher category. He used Meigen's stain technique (Meigen, 1903) which is not too satisfactory in finely crystalline samples. A quicker and more accurate x-ray method was developed by Chave (1954a) and used by Lowenstam (1954a) to determine aragonite percentages in shell material. Lowenstam found that the percentages of calcite and aragonite in certain groups of invertebrates were related to the temperature of the water in which shell deposition took place.

Vinogradov (1953) discussed the history of the biogeochemistry of marine organisms and summarized scattered chemical analyses. Clark & Wheeler (1922) have studied shell mineralogy and chemistry and have noted a relationship between chemistry, mineralogy, and water temperature. Strontium and magnesium in organically precipitated calcium carbonate have recently been investigated rather comprehensively. Tsuchiya (1944) analyzed corals; Odum (1950) has studied the biogeochemistry of strontium; Kulp, Turekian & Boyd (1952) have studied the strontium contents of limestones and fossils, and Chave (1954a,b) has investigated the biogeochemistry of calcareous marine organisms and fossils. Thompson & Chow (1955) have analyzed the strontium content of the shells of large numbers of invertebrates and have shown that the strontium-calcium atom ratios in marine organisms appear to be constant in accordance with their phylogenetic classification. Krinsley & Bieri (1959) have analyzed pteropod shells for a number of trace elements, and Lowenstam (1954b) has discussed the status of current investigations in the biogeochem-

istry of shell material. Recently Lowenstam (1959) has shown that the O^{18}/O^{16} ratios and $SrCO_3$ and $MgCO_3$ contents of the calcitic shells of recent articulate brachiopods are related to temperature; these relationships permit the separation of original and diagenetically modified abundances of these three properties in fossil species. Revelle & Fairbridge (1957) have summarized much of the information available on carbonates and have published an extensive bibliography.

To date, there is little information available on environmental variation in the trace element composition of shells. Further, the utility of these measures is dependent upon knowledge of their stability through the time-diagenetic zone.

The author is particularly indebted to Ralph Johnson for his constructive criticism. He also wishes to thank Robert L. Miller, Edwin Shykind, and Herbert Barghusen for stimulating discussions. Marie Levonian and Marita Campbell helped with specimen preparation and selection.

METHODS

Two rocky beach littoral gastropods, *Tegula funebralis* (A. Adams) and *Fissurella volcano* Reeve, and one sandy bottom gastropod, *Olivella biplicata* (Sowerby), were selected for study. The species chosen had to be associated reasonably close together geographically, had to be readily available, and also had to be fossilized together. This severely limited the choice of species and made collecting rather difficult. Five modern assemblages ranging from southern California to Washington were sampled to provide an extensive environmental range. Calcite-aragonite ratios and trace elements (magnesium and strontium) were determined for the same three species within these localities. *Fissurella*, however, was not present at one locality and was therefore not analyzed. The same three species were studied in one Pleistocene formation, while two of the species (*Olivella* and *Tegula*) were examined in two other Pleistocene formations.

A sample of ten specimens of each species from each locality was used to give a reasonably comprehensive sample of the population present at that locality. Three species were used as a check against each other and to determine whether there was any difference between species at a given locality.

An extra ten specimens of *Tegula* collected from shell heaps on the beach at Palos Verdes (D) have been compared with ten specimens of the same species collected alive from that locality. Eleven calcite-aragonite ratios on *Tegula* and *Fissurella* have not been determined for various reasons, usually the small sample size. All modern specimens of *Tegula* except the D locality specimens (Table 1) were alive when collected; all modern specimens of *Olivella* except the locality B specimens (which were collected live) were selected from shell heaps on the beach. All modern *Fissurella* specimens were collected from shell heaps.

Five localities along the Pacific Coast, were chosen as the lowest number which might reasonably represent a comprehensive sample of a large part of the geographic ranges of these species. The localities were chosen as far apart as was practicable so that a reasonably extensive temperature range might be represented (Table 1).

CHOICE OF VARIABLES—RATIONALE

Strontium and magnesium concentrations and calcite-aragonite ratios were selected for analysis. Manganese analyses on these same shells have been published elsewhere (Krinsley, 1959). Magnesium and strontium are present in amounts suitable for analysis in the species examined and have been studied by various workers to the extent that some information is available. Magnesium temperature scales has been proposed (Chave, 1954a); it has also been suggested that strontium may be directly related to temperature (Lowenstam, 1954b). Neither of these two trace elements has been investigated systematically in large numbers of modern and fossil shells representing the same species. Many other elements, although present in large amounts, are difficult to measure accurately or could not be used due to the method of analysis, laboratory contamination, etc.

Since strontium is presumably in the aragonite structure, and magnesium in the calcite structure, it was necessary to examine calcite-aragonite ratios in the shell

TABLE 1.—MAGNESIUM, STRONTIUM, AND ARAGONITE MEANS AND STANDARD DEVIATIONS IN THREE SPECIES OF GASTROPODS

Loc.	*Olivella*					*Tegula*						*Fissurella*					
	ppm					ppm						ppm					
	Sr		Mg		Ar. %	Sr		Mg		Ar. %		Sr		Mg		Ar. %	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
A	990	72	150	44	100	1290	126	500	61	54	8	1000	137	780	215	66	7
B	1160	51	130	20	100	1410	153	490	89	64	6	790	158	540	123	60	6
C						1250	153	420	95	76	11						
D	1210	221	250	41	100	1400	168	420	82	92	4	1150	137	730	149	61	13
E	1270	175	140	30	100	1240	191	400	98	75	8	880	92	700	127	53	8
F	1160	180	140	28	100	1340	237	440	74	65	12						
X	1290	350	390	212	100	1280	119	190	56	70	26	1030	102	600	158	57	11
Y	1710	250	80	9	100	1450	325	290	152	87	13						
Z	1750	231	310	211	100	1630	360	390	158	81	8						

Modern Animals	
Location Letter	Location
A	Scripps Institute of Oceanography, La Jolla, California
B	Scripps Cove Park, La Jolla, California
C	Palos Verdes, California (collected live)
D	Palos Verdes, California (collected from shell heaps)
E	Shell Beach, California
F	Neah Bay, Washington
Fossils	
X	Ocean Beach, California
Y*	San Pedro, California
Z*	Pacific Beach, California

* Localities Y and Z represent equivalent ages.

material to determine what effect polymorph composition had upon trace element relationships. Lowenstam (1954a) has suggested that there is a relationship between temperature and calcite-aragonite ratios while other workers have indicated that polymorph composition affects the uptake of trace elements. The situation is complicated, but it seems that the traces are inseparately related to polymorph shell composition.

The problem of change with time in shell trace element composition is extremely complex. A number of assumptions are implicit in a study of this kind.

It is assumed that the composition of the oceans has remained the same through time; at least as far back as the Pleistocene (Vinogradov, 1953; Conway, 1943; Odum, 1950). It is likewise assumed that animals are able to concentrate certain trace elements (within certain limits) over wide ranges of sea water composition (Svedrup, Johnson & Fleming, 1942).

It seems reasonable to believe that enough evolutionary change to affect the conclusions reached here over the period of time represented by the fossil samples has not occurred. Invertebrates have evolved relatively slowly, and one million years is not a great period of time, geologically speaking. Morphologically, the animals involved in this study have not changed as far as can be determined; even shell colors, where present, seem to be identical with their modern counterparts. The assumption is also made that the modern ranges of trace elements approximate the limits of all the fossils previous to burial. This point is difficult to check, but shell collections on a beach have been compared with animals living on that beach at any one time, and the assumption seems warranted.

It is also considered (Lowenstam, 1954b; Vinogradov, 1953) that phylogenetic groups of animals have a relatively fixed trace element content. If this were not the case, the problem could not be investigated, as the idea implicit in this paper is the examination of modern animals, the determination of their trace element ranges, and the use of these as an estimate of the parameters of the original fossil populations.

If all these assumptions are correct, any

change from modern to fossil material should be an expression of post-depositional change.

PREPARATION OF SAMPLES FOR ANALYSIS

The snails were preserved in alcohol. Those animals which had no organic material in them, *i.e.*, empty shells, were kept tightly sealed in glass jars. When needed for analysis, the shells were examined and a description written of their condition. Where necessary, the organic material was removed by hand. Chlorox has been used to eliminate organic material (Lowenstam, 1954a), and it was considered at first that the organic material within the shell might contain sizeable amounts of the two trace elements examined. However, several specimens were examined with this view in mind; parts of several specimens were chloroxed and portions were not. It was found that there was no difference between the chloroxed specimens and the non-chloroxed specimens as far as both trace elements were concerned within experimental error. The individual shells were crushed and partially ground in a diamond mortar. The material was then ground to a finer powder in an agate mortar. It was finally passed through a 200-mesh bolting-silk screen.

At various stages in the grinding, calcite-aragonite ratios were examined to determine whether any conversion had taken place; no difference within experimental error was noted.

The samples were arced in a Jarrel-Ash 21′ spectrograph with calcium as an internal standard using a method developed at the University of Chicago by O. Joensuu. A modified Stallwood blower (Stallwood, 1954) as developed by Joensuu was used to steady the arc and improve reproducibility.

Reproducibility for strontium and magnesium analyses was $\pm 10\%$. All samples were run at least in duplicate.

Calcite-aragonite ratios were determined using a North American Phillips x-ray diffraction unit. The ratios of the respective principal peaks of aragonite and calcite were compared. Reproducibility in a given sample was approximately $\pm 5\%$ using a method devised by Peter Bragg of the Portland Cement Association for eliminating preferred orientation.

STATISTICAL TESTS

The results of all analyses on trace elements and aragonite percentages are indicated in Table 1. The first statistical test performed was analysis of variance, single variable of classification (Dixon & Massey, 1951), to test the hypothesis that means from several localities with respect to a single variable came from the same population. The second test concerned variances of several populations to test the hypothesis that the variances from several localities with respect to a single variable compared came from the same population (*op. cit.*). These two tests, of course, compared a number of localities *in toto* and did not distinguish between individual localities. When this was desired, small sample statistics were used with respect to means (Robert L. Miller, personal communication). The substitute t test for means was used (Dixon & Massey); this tests the significance of differences between individual means. This test is adequate for samples of 10 or less. Individual variances were compared using the F distribution (*op. cit.*). When it was necessary to compare two variables, linear regression was used (*op cit.*).

The variance s^2 is a useful statistic for analysis of variance computations and other tests performed and so it is used throughout this paper. However, the standard deviation, s, is used in Table 1 to give a somewhat clearer physical picture of the variation. It will be remembered that, for a normal distribution, about two-thirds of the observations differ from the mean by less than the standard deviation, 95% by less than twice the standard deviation, and almost all by less than three times the standard deviation.

The results of these tests are given in Tables 1, 2, 4, and 5.

COMPOSITION OF MODERN ANIMALS

ARAGONITE

The aragonite mean range in *Tegula* varies from 54 to 92 percent (Table 1). That significant differences exist between the arago-

TABLE 2.—STATISTICAL TESTS

Sample Localities	Magnesium		Strontium		Aragonite	
	$\bar{x}$	s^2	$\bar{x}$	s^2	$\bar{x}$	s^2
(*Olivella*)						
ABDEF	R	a	R	r		
ABEF	A	a				
ABEF & X	R	r				
ABEF & Y	R	r				
ABEF & Z	R	r				
(*Tegula*)						
ABCDEF	A	a	A	a	R	r
ABCEF					R	r
ABCDEF & X	R	a	A	a		
ABCDEF & Y	R	r	A	a		
ABCDEF & Z	A	a	R	a		
(*Fissurella*)						
ABCE	R	a	R	a	A	a
ABCE & X		a		a	A	a

Analysis of variance; Single variable of classification (.99 level).
A = Accept hypothesis of equal means.
R = Reject hypothesis of equal means.
Equal and unequal variances (.99 level).
a = Accept hypothesis of equal variances.
r = Reject hypothesis of equal variances.

nite sample means and variances in *Tegula* is indicated in Tables 2 and 4, summaries of the statistical tests used in this paper. This is the case when the five modern localities are compared and also when the Palos Verdes (D) specimens are compared with the others. Assuming that aragonite and temperatures are correlated (Lowenstam, 1954a), the differences probably represent different environmental microtemperature niches.

Oxygen isotope determinations were made on several specimens of *Tegula* shells through the courtesy of H. Craig and C. Emiliani. Although littoral benthonic animals such as *Tegula* may not give the best temperature determinations due to differences in the isotopic composition of the water in which they live as compared to oceanic isotopic water composition, it can be seen from Table 3 that the isotopic temperatures parallel mean water temperatures. It can also be seen from the same table and from Table 1 that aragonite percentages are not related to measured water temperatures or to oxygen isotope temperature determinations.

It is apparent that no aragonite temperature scale such as Lowenstam (1954a) has suggested can be constructed over the temperature range indicated for *Tegula* (about 7°C.); his temperature ranges (0 to approximately 28°C.) were considerably greater than the ranges in this study. Individual specimens would have to be checked for oxygen isotope temperatures along with aragonite percentages since the possibility exists that the individuals at each locality secreted their shell material at different temperatures representing different times of the year.

The rather large mean difference between the two *Tegula* Palos Verdes samples (C

TABLE 3.—SURFACE WATER TEMPERATURES AT MODERN AND FOSSIL LOCALITIES AS DETERMINED BY DIRECT READING AND BY THE O^{18}/O^{16} METHOD, ON *Tegula*

Localities	Water Temperatures			O^{18}/O^{16} Temperatures		Spread °C.
	Mean* °C.	Max.* °C.	Min.* °C.	Individuals °C.	Average °C.	
A & B	16.7	22.2	10.6	18.7 18.2 17.7 18.8	18.3	17.2–19.3
C & D	16.7	24.4	10.0			
E	13.3	18.9	9.4	14.6		14.1–15.1
F	9.8	17.8	2.2	12.8		12.3–13.3
X				16.5		16.0–17.0

The accuracy of the O^{18}/O^{16} method is ±.5°C.

* U. S. Dept. Commerce, 1952.

TABLE 4

Olivella—Strontium-Means

	A	B	D	E	F	X	Y	Z
A		R	R	R	R	R	R	R
B			A	A	A	A	R	R
D				A	A	A	R	R
E					A	A	R	R
F						A	R	R
X							R	R
Y								A

Olivella—Strontium-Variances

	A	B	D	E	F	X	Y	Z
A		A	R	R	A	R	R	R
B			R	R	R	R	R	R
D				A	A	A	A	A
E					A	A	A	A
F						A	A	A
X							A	A
Y								A

Tegula—Aragonite-Means

	A	B	C	D	E	F
A		R	R	R	R	R
B			R	R	R	A
C				R	A	R
D					R	R
E						A

Tegula—Aragonite-Variances

	A	B	C	D	E	F
A		A	A	A	A	A
B			A	A	A	R
C				R	A	A
D					A	R
E						A

Fissurella—Magnesium-Means

	A	B	C	E	X
A		R	A	A	R
B			R	R	A
C				A	R
E					A
X					

Fissurella—Strontium-Means

	A	B	C	E	X
A		R	A	A	A
B			R	A	R
C				R	A
E					R

A—Accept hypothesis of equal means or variances at .99 level.
R—Reject hypothesis of equal means or variances at .99 level.

and D) with respect to aragonite might indicate a very gross change in temperature within the immediate past if aragonite percentages can be correlated with temperature, but the necessary evidence is not available. Carbon isotopic dating and oxygen isotope temperature determinations would be applicable here.

It is tempting to speculate on the mean water temperature at the Ocean Beach (X) fossil locality. If *Tegula* secretes shell material at a temperature somewhat above the mean temperature of the locality concerned (Table 3), then the Ocean Beach specimens may represent a mean water temperature somewhere in the vicinity of 14° or 15°C., which is somewhat lower than the present mean temperature.

Olivella is composed of 100% aragonite; no exceptions were noted in this study.

Significant differences do not exist between the aragonite means and variances in *Fissurella* (Table 2); the range in the *Fissurella* means with respect to aragonite is less than that of *Tegula* (Table 1).

No temperature scale seems practicable in *Fissurella* with respect to aragonite over the range from which these samples were taken. Moreover, since *Fissurella* moves out into the water as it ranges northward, the temperature differential between localities would probably be increased and allow more opportunity for a temperature scale if one were possible.

STRONTIUM

There were no significant differences in strontium content between sample means and no difference in variances at the six modern localities with respect to *Tegula* (Table 2), even though the aragonite percentages varied somewhat. This element likewise seems to be rather constant in pteropod shells (Krinsley & Bieri, 1959) and in foraminiferal tests (Emiliani, 1955). It is probable that strontium is relatively invariable here due to some physiochemical factor related to the genetic makeup of the organisms.

There is no relationship between mean,

maximum, or minimum strontium content and temperature in modern specimens of *Tegula*.

In *Olivella*, significant differences in strontium concentrations exist between the sample means and between sample variances at the five modern localities (Table 2). The variances in *Olivella* are significantly lower at localities A and B than at the other three modern localities (Tables 1 and 2).

The variability with respect to any measure in animals may be less in a restricted area than in a broad one; this could be due to the restricted ecologic and genetic conditions prevailing in the area. This seems to be the case with *Olivella* at Scripps Cove Park (B); these specimens were all collected at one time, live, in 20 feet of water within a radius of about 10 feet. All other *Olivella* specimens were collected over considerably wider areas and did not contain the living animal; these latter specimens were more variable than those at B. The "live" *Olivella* specimens represent a modern restricted geographic and time horizon of no more than several years.

The strontium variance is statistically lower at B than at three other localities; the mean is statistically the same as at the other localities excepting A (Table 4). Although magnesium variances in modern *Olivella* are statistically the same, locality B has the lowest (Tables 1 and 2). Again, the magnesium mean at B does not differ from other modern localities excepting D (Table 2). In other words, with respect to the two trace elements, strontium and magnesium, we find numerically lower variances at B than in the remaining samples and means that do not generally differ significantly from the rest of the modern samples.

The paleoecologic value of a restricted time horizon (key bed, diastem, etc.) is reasonably obvious. If it were possible to identify this type of horizon in a modern situation by examining variability in trace element content of shells, then fossil horizons might be selected in the same manner. The assumption would have to be made that no trace element movement within the shell material had occurred with time; it may be possible in some situations to make this assumption (see discussion of fossil *Tegula*). Emery, Tracey & Ladd (1954) have shown that limestones at Bikini show *some* (italics mine) recrystallization of aragonite in thin section. Spectrographic studies revealed no apparent change in the strontium content of the carbonate. However, the strontium calcium ratio diminishes markedly when recrystallization occurs (Revelle & Fairbridge, 1957).

The sample means are significantly different in *Fissurella* at the four modern localities; the sample variances, however, are not (Table 2). No reasons can be given for this phenomenon.

MAGNESIUM

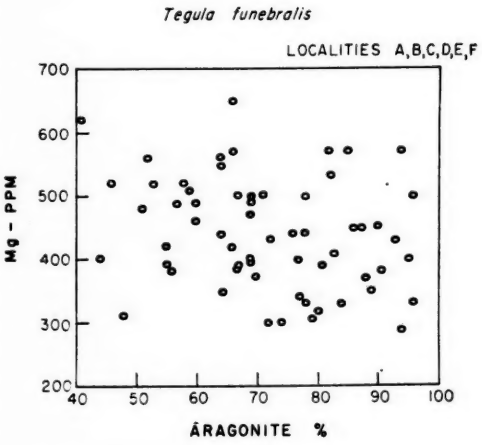
The magnesium means and variances do not differ significantly in modern *Tegula* (Table 2). Magnesium seems to be quite stable in modern *Tegula* in spite of the fact that aragonite percentages vary; this was also true of strontium. The suggestion is made that modern magnesium and strontium concentrations here might be useful in assessing trace element movement in fossils.

As in the case of strontium, *Tegula* specimens collected after death at D do not differ significantly in magnesium mean and variance from those specimens collected live at the same locality (C). No relationship exists between the mean, maximum, or minimum magnesium content and temperature; this may be due to the relatively narrow range of temperature in this study (7°C., Table 3). Chave (1954a) found a relationship between magnesium and temperature over a range of 30°C. and weight percentages of magnesium carbonate from 0 to 25% in various groups of marine skeletal elements; the magnesium and temperature ranges in this study are considerably less than those he reported.

If magnesium and aragonite in modern specimens of *Tegula* are compared (Text-fig. 1 and Table 5), an inverse relationship between the two variables can be seen and demonstrated statistically. No relationship is found between aragonite and strontium in modern shells. The mineralogical form of the carbonate apparently exerts an effect on the amount of magnesium in the structure. Chave (1954a) has shown that three factors control the amount of magnesium in the shells of calcareous marine organisms: the phylogenetic level of the organisms in-

volved, the temperature of the water in which the shell material was secreted, and, finally, the skeletal mineralogy. The first two factors would appear to be relatively constant here, but there is some variation in the mineralogical composition of the shells under discussion; the relationship between magnesium and aragonite therefore seems reasonable.

In *Olivella* the magnesium mean at D differs significantly from the other locality means. The magnesium variances are not significantly different at the five modern localities (Tables 1 and 2) although the B specimens, as noted above, have the lowest variance in the population (Table 1). It is interesting to note that there is less magnesium in *Olivella* than in either *Tegula* or *Fissurella;* this is probably due to the 100 percent aragonite content of the former. There is also apparently no relationship be-



TEXT-FIG. *1*—Plot of magnesium and aragonite in all modern specimens of *Tegula funebralis.*

TABLE 5.—CORRELATION COEFFICIENTS

R—Reject hypothesis that the two variables indicated below are correlated at the .975 level.
A—Accept hypothesis that the two variables indicated below are correlated at the .975 level.

Tegula—Six modern localities combined, ABCDEF; Aragonite and Magnesium.

A

Tegula—Six modern localities combined, ABCDEF; Aragonite and Strontium.

R

Tegula—Fossil locality X; Aragonite and Magnesium.

R

Tegula—Fossil locality Y; Aragonite and Magnesium.

A

Tegula—Fossil locality Z; Aragonite and Magnesium.

R

Tegula—Fossil localities X, Y & Z, each taken individually; Aragonite and Strontium.

R

Fissurella—Four modern localities combined, ABCE; Aragonite and Magnesium.

R

Fissurella—Four modern localities combined, ABCE; Aragonite and Strontium.

R

Fissurella—Fossil locality X; Aragonite and Magnesium.

R

Fissurella—Fossil locality X; Aragonite and Strontium.

R

tween temperature and magnesium content in any of the three species.

The magnesium means are significantly different in *Fissurella* at the four modern localities; the variances, however, are not (Tables 2 and 4).

FOSSILS

ARAGONITE

All three fossil species have large percentages of aragonite; no conversion with time has occurred in *Olivella* and probably none in *Fissurella*. Little can be said concerning aragonite conversion in *Tegula*. The Ocean Beach (X) *Tegula* specimens have the same means as all modern specimens except those from D. The other two groups of fossils (Y and Z) have somewhat less aragonite than the D specimens (Table 1), but considerably more than all other modern specimens. The variance in X locality specimens is considerably larger than in the D group; all other modern and fossil variances are essentially the same.

If aragonite is *grossly* correlated with temperature (Lowenstam, 1954a), then the higher aragonite concentrations at Y and Z may represent a warmer environment than exists in these areas at present. Hertlein & Grant (1944) state that certain southern faunal elements ranged much further north than they do today during that part of the Pleistocene represented by Y and Z, indicating that the temperature was somewhat higher in these areas at that time. Any change in aragonite percentages with time should cause a decrease in aragonite since it is less stable than calcite. Therefore, the higher aragonite content of the fossils is real and of course may originally have been even higher.

Fissurella aragonite means and variances at locality X do not differ from those at all four modern localities (Table 2). This would indicate little change in the fossils at locality X with respect to aragonite; more generally little change has occurred in *Fissurella* shells during the time period examined in this paper. *Fissurella* apparently reacts differently than *Tegula* or *Olivella* to postdepositional change, possibly due to the different physical structure of the shell material (Boggild, 1930). Another indication of little change in the *Fissurella* shells at fossil locality X as compared to modern specimens is the lack of relationship between aragonite and magnesium (Table 5); note that this was not the case in *Tegula* (the relationship approximates a straight line at locality X; see discussion below).

STRONTIUM

There is no difference between modern strontium means and fossil means in *Tegula* at localities X and Y although Z does differ from the modern situation. There is no difference between modern and fossil variances in *Tegula* with respect to strontium (Table 2).

Strontium is relatively stable in *Tegula* over the time period examined; however, locality Z has somewhat more strontium than would be expected. Note also that variability is high here, although within the .99 limit. Either some movement of strontium has occurred with time, sampling was not random, or some physical or genetic factor was involved; the former seems more likely.

As indicated above, under some circumstances, strontium can pass relatively unchanged through the time-diagenetic zone, at least with respect to *Tegula*. The lack of strontium movement may also be related to the mineralogical composition of *Tegula* as compared to *Olivella;* calcitic shells should be examined with this view in mind. Recrystallization to calcite would be expected to change the strontium content considerably; one Pliocene specimen of *Tegula* was analyzed which had converted to calcite and contained only 425 ppm. of strontium. Along these same lines, Thompson & Chow (1955) have shown that calcareous marine deposits have lost strontium during geologic time. Aragonite to calcite conversion would be expected to decrease the amount of strontium in carbonate rocks.

The fact that *Tegula* fossils at localities X and Y do not differ from those at the modern localities, and that specimens from locality Z do, stresses the importance of local diagenetic conditions in the movement of strontium. However, locality Z is relatively close to X and Y in terms of absolute figures, indicating relatively little strontium movement.

Olivella fossils from localities Y and Z are

significantly different from all modern specimens as far as strontium means are concerned (Table 4). The *Olivella* specimens from locality X differ from the A shells but do not differ from the other four modern groups with respect to means. Specimens from localities X and Y, and X and Z, differ from each other significantly with respect to means; Y and Z do not.

Strontium variances at A and B differ significantly from X, Y, and Z specimens; while D, E, and F are the same as X, Y, and Z in *Olivella*. X, Y, and Z do not differ with respect to strontium variances (Table 4).

The increased amount of strontium at localities Y and Z can be explained in several ways. It may be due to diffusion into the shell material from the surrounding sediments with time; this seems probable, as indicated above. The possibility also exists that these localities contained slightly higher sea water concentrations of strontium than at present and that trace element uptake was related to the concentration. Odum (1950) has shown that concentrations of strontium in certain fresh water gastropods are a function of the concentration of the aqueous medium.

Fissurella specimens at fossil locality X (no other fossil *Fissurella* localities were sampled) differ from modern localities B and E but not from A and C with respect to strontium means; modern and fossil variances are the same. The means data suggest two different groups; the fossils are part of one of these groups. Nothing at present can be said about the factors that control this situation. The modern and fossil variances suggest that no strontium movement has occurred at locality X.

Olivella specimens at Y and Z contain more strontium than corresponding *Tegula* specimens; it is apparent that addition of strontium has occurred in fossil *Olivella* at these two localities. The larger amount of aragonite in *Olivella* as compared to *Tegula*, and the difference in shell structure of the two species, would account for the difference in strontium concentrations.

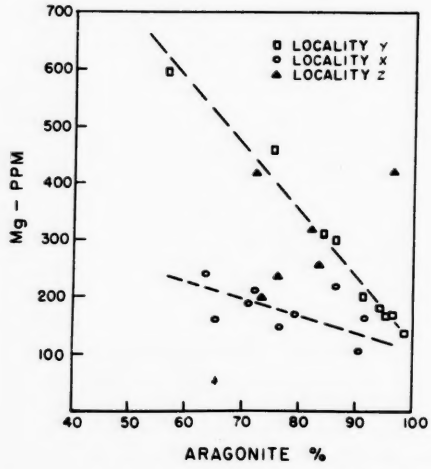
Finally, solubility product data indicate that the quantity of strontium present in a carbonate rock (shells after burial are essentially carbonate rocks) at the time of deposition would remain essentially unchanged after deposition, because preferential leaching of this element is impossible without complete solution and removal of the calcium carbonate (Zeller & Wray, 1956). This would explain the fact that there has been no apparent leaching of strontium in any of the three gastropod species with time, except for the single *Tegula* specimen which had recrystallized and lost strontium. However, the larger strontium content in some of the fossils with time can be explained by assuming that aragonite can hold a considerably larger amount of strontium than is usually present in shell material (Kulp, Turekian & Boyd, 1952; Odum, 1950). It should also be noted that the increase in strontium is very small and is on the order of several hundred parts per million over a span of perhaps several hundred thousand years.

MAGNESIUM

Tegula specimens at X and Y are significantly different from modern localities with respect to magnesium means; Z specimens are not. The variance at Y is significantly different from all six modern variances in *Tegula;* specimens from X and Z are the same (Table 2).

A correlation exists between magnesium and aragonite at Y; no correlation between these two measures is found at X or Z (Table 5), although the relationship between the two at X does approximate a straight line. This high inverse correlation between magnesium and aragonite at Y ($r = -.986$) and the much lower correlation in modern specimens ($r = -.330$) indicates that there has been magnesium movement at Y (and possibly at X) and that equilibrium conditions may have prevailed here (Text-fig. 2). After death and burial, shells are simply crystals of calcium carbonate and react as such to time, pressure, and temperature changes in sediments. The lack of correlation between the two variables at X and Z is probably due to different post-depositional conditions at each location.

Tegula shells from localities X and Y seem to have lost magnesium with time, which may be due to the high solubility of this element. Magnesium is soluble at a pH which would permit it to go into solution under conditions which could allow it to be selectively removed from calcium carbonate



TEXT-FIG. 2—Plot of magnesium and aragonite in *Tegula funebralis* at three fossil localities.

(Zeller & Wray, 1956). *Tegula* shells at Z are within the modern magnesium range; this suggests that conditions prevailing after burial in formations of approximately the same age differ considerably and thereby permit different rates of trace element movement in the same species.

All three fossil means are significantly different from the modern *Olivella* means, excluding D. The fossil variances are significantly different from all five modern variances in *Olivella* (Table 2).

Magnesium seems to have moved into shell material at X and Z in *Olivella* and to have been leached from shells at Y. The means and variances at X and Z in *Olivella* have increased with time while those at Y have decreased substantially; again the importance of local diagenetic history is indicated. It is difficult to account for the large increase in magnesium at the two *Olivella* fossil localities; theoretically it should be removed from calcium carbonate. The large variances at X and Z also indicate differential magnesium movement with time. Low variability at locality Y probably indicates that loss of magnesium has "evened out" variability differences. It is also important to note that magnesium and strontium have reacted quite differently to post-depositional conditions at the same locality.

In both *Tegula* and *Olivella* where apparent increase in magnesium and strontium has occurred, variability has increased, while loss of magnesium seems to be associated with decreased variability in *Olivella*. Diffusion experiments would help to solve the problem.

Modern and fossil variances in the three measures studied here may permit the degree of diagenetic change with time to be determined. If this is the case, it might then be possible to eliminate the complicated and costly determinations of O^{18}/O^{16} isotope ratios in shells to determine whether diagenetic alteration has occurred, as discussed by Lowenstam (1959); modern and fossil variances could then be compared and those shells which had altered could be eliminated. Further studies on this subject would seem warranted.

The *Fissurella* magnesium mean at X is significantly different from that at A and C; it is the same as at localities B and E (Table 4). Modern and fossil magnesium variances in *Fissurella* do not differ (Table 2). Again it is evident that little if any diagenetic change has occurred in this species. There is no correlation between aragonite and magnesium in *Fissurella* fossils; further, variances in magnesium, as in strontium, do not differ significantly from the modern situation.

SUMMARY

Decrease in the variance of magnesium and strontium at a particular place as related to other localities may indicate a restricted time horizon, as seemed to be the case at locality B with respect to *Olivella* but not *Tegula*.

The difference is probably related to the varying aragonite content of the latter; calcitic shells should be examined to determine whether decrease in trace element variability is characteristic of limited geographic areas.

The variation detected in the measures examined does not seem to be related to any obvious environmental factors, although only a limited number were examined. However, since strontium in modern and fossil shells may be related to the composition of sea water in which they grew (Odum, 1950), and strontium in unrecrystallized shell material of certain species appears to be stable with time, it

may be possible to assess the strontium content of ancient seas. However, as Lowenstam (1959) has pointed out, the composition of sea water may not have changed significantly since the Mississippian.

Olivella and in some cases *Tegula* seem to have been affected by post-depositional change; magnesium content has been affected more than strontium. Magnesium in *Olivella* shells from different localities of equivalent ages may move either in or out of aragonitic shell material. On the other hand, no such phenomenon is observed in *Tegula;* it is probable that both the mineralogical composition and the shell structure are responsible.

The speed and degree to which diagenesis can occur are largely unknown. Fossils offer an excellent opportunity to measure physical and chemical changes that have occurred with time, since the original composition of the shell material can be determined approximately in many cases and compared with the final composition. In this sense, fossils represent an extended diffusion experiment.

REFERENCES

BOGGILD, O. B., 1930, The shell structure of mollusks: k. Dansk. Vidensk. K. Skr. Naturvidensk. K. Math. afd., Raekke 2, p. 232–326.

CHAVE, K. E., 1954a, Aspects of the biogeochemistry of magnesium 1. Calcareous marine organisms: Jour. Geology, v. 62, p. 266–283.

——, 1945b, Aspects of the biogeochemistry of magnesium 2. Calcareous sediments and rocks: Jour. Geology, v. 62, p. 587–599.

CLARKE, F. W. & WHEELER, W. C., 1922, The inorganic constituents of marine invertebrates: U. S. Geol. Survey, Prof. Paper 124, p. 1–62.

CONWAY, E. J., 1943, Chemical evolution of the ocean: Royal Irish Acad., Proc., v. 48B, p. 161.

DIXON, W. J. & MASSEY, F. J., 1951, Introduction to statistical analysis: McGraw-Hill Book Company.

EMERY, K. O., TRACEY, J. I. & LADD, H. S., 1954, Geology of Bikini and nearby atolls: U. S. Geol. Survey, Prof. Paper 260A, 265 p.

EMILIANI, C., 1955, Mineralogical and chemical composition of the tests of certain pelagic Foraminifera: Micropaleontology, v. 1, p. 377–380.

HERTLEIN, G. H. & GRANT, U. S. IV, 1944, The geology and paleontology of the marine Pliocene of San Diego, California: San Diego Soc. Nat. Hist., Mem., Vol. II.

KRINSLEY, D., 1959, Manganese in modern and fossil gastropod shells: Nature, v. 193, p. 770–771.

KRINSLEY, D. & BIERI, R., 1959, Changes in the chemical composition of pteropod shells after deposition on the sea floor: Jour. Paleontology, v. 33, p. 682–684.

KULP, J. L., TUREKIAN, K. & BOYD, D. W., 1952, Strontium content of limestones and fossils: Geol. Soc. America, Bull., v. 63, p. 701–716.

LOWENSTAM, H. A., 1954a, Factors affecting aragonite-calcite ratios in carbonate secreting marine organisms: Jour. Geology, v. 62, p. 284–322.

——, 1945b, Status of invertebrate paleontology, 1953, XI. Systematic paleontologic and evolutionary aspects of skeletal building materials: Mus. Comp. Zoology, Bull., v. 112, no. 3, p. 287–317.

——, 1959, O^{18}/O^{16} ratios and strontium and magnesium contents of calcareous skeletons of recent and fossil brachiopods and their bearing on the history of the oceans: Int. Oceanogr. Congress Preprints, p. 71–72, Abstract.

MEIGEN, W., 1903, Beiträge zur Kenntnis des kohlensauren Kalk: Naturwiss. Gesell. Freiburg Berlin, v. 13, p. 1–55.

MILLER, R. L. & OLSON, E. C., 1955, The stability of quantitative properties as a fundamental criterion for the study of environments: Jour. Geology, v. 63, p. 376–387.

ODUM, H. T., 1950, Biogeochemistry of strontium: Unpublished Ph.D. thesis, Yale Univ.

REVELLE, R. & FAIRBRIDGE, R., 1957, Carbonates and carbon dioxide: Geol. Soc. America, Mem. 67, v. 1, p. 239–296.

STALLWOOD, B. J., 1954, Air cooled electrodes for spectrochemical analysis of powders: Jour. Optical Soc. America, v. 44, p. 171–176.

SVEDRUP, H. U., JOHNSON, M. W. & FLEMING, R. H., 1942, The Oceans: Prentice-Hall, Inc.

THOMPSON, T. G. & CHOW, T. J., 1955, The strontium-calcium atom ratio in carbonate secreting marine organisms: Papers in Marine Biol. and Oceanography, supp. v. 3, Deep-Sea Res., p. 20–39.

TSUCHIYA, Y., 1944, Distribution of strontium in calcareous organisms. I. Strontium content of reef-forming corals: Chemical Soc. Japan, Jour. Agronomy, v. 20, p. 653–654.

U. S. DEPT. OF COMMERCE, 1952, Surface water temperatures at tide stations, Pacific Coast, North and South America and Pacific Oceanic Islands: U. S. Coast and Geod. Survey, Spec. Pub. 280, Washington, D. C.

VINOGRADOV, A. P., 1953, The elementary chemical composition of marine organisms: Sears. Found. for Marine Res., Yale University.

ZELLER, E. J. & WRAY, J. O., 1956, Factors influencing precipitation of calcium carbonate: Am. Assoc. Petroleum Geologists, Bull., v. 40, p. 140–152.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 4, P. 756–762, 2 TEXT-FIGS., JULY, 1960

PALEONTOLOGICAL NOTES

PHOTOGRAPHY OF PALEOZOIC ARENACEOUS FORAMINIFERA

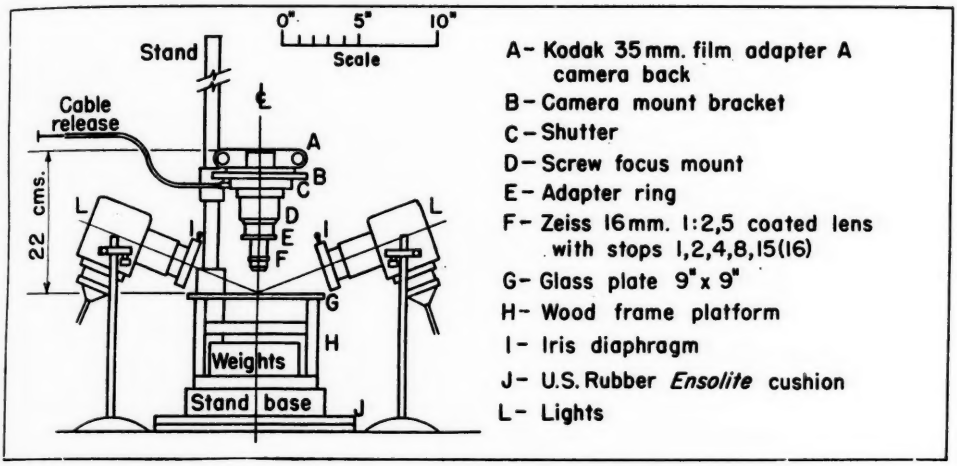
R. C. GUTSCHICK
University of Notre Dame, Notre Dame, Indiana

A method and procedure is outlined for photographing Paleozoic arenaceous Foraminifera, particularly those obtained from acid residues. The difficulty in obtaining such photographs has restricted the usage of this type of illustration.

There have been relatively few taxonomic papers on Paleozoic arenaceous Foraminifera, particularly those dealing with faunas extracted from acid residues. Illustrations have usually been drawings which in the absence of photographs leave much to be desired and necessary for proper documentation. There has been reluctance on the part of many authors to use good unretouched photographs because it has been difficult to get good definition through adequate depth of field and proper lighting. Recently we have had reasonable success in getting good photographs of lower Mississippian arenaceous foraminifers obtained from acid residues (Gutschick & Treckman, 1959). This brief summary has been prompted by a number of inquiries concerning the method which was used to obtain the illustrations in the above paper. A number of excellent articles have been published on the subject by Triebel, 1947; Fournier, 1950, 1954, 1956, and 1957; Sander, 1955; Cummings, 1956; Kugler, 1957; and others. The pinhole method was tried unsuccessfully. The method used is not particularly unique and incorporates many of the ideas from the above contributions. Much credit goes to John Treckman and John Weiner, former students who have helped to develop and perfect the results.

Preparation of specimens.—Rock material is treated with hydrochloric acid to obtain the residue which is water washed to eliminate the clay, dried and washed in alcohol, and slow dried to produce discrete particles. Individual fossils are then picked out and treated with alcohol and glycerin. The specimen(s) is placed on a clean 1×2 or 2×3 inch glass microscope slide. A small camel's hair brush is dipped into alcohol, and then glycerin is applied carefully to the fossil on the plate. The mixture can be thinned with alcohol if it is too thick, and the specimen can later be cleaned with alcohol. The fossil is extracted from the puddle of alcohol-glycerin mixture and oriented on a clean slide. It is not necessary to be hasty with this operation for the specimen will remain coated properly for several hours or longer. The results for coarse-textured granular forms are improved with the use of glycerin, and smooth-textured forms come out better with very little or no glycerin. One can expedite the work by mounting several specimens on one slide for a single exposure, providing they have the same or similar sizes, shapes, and surface characteristics for proper lighting and depth of field. The glass slide with the specimen(s) is placed on the 9×9 inch glass plate stage for the photography.

Photography.—The equipment used is a Gamma Universal Photomicrographic Camera Model U with Kodak 35 mm. Film Adapter A camera back and Zeiss-Winkel 16 mm. 1:2,5 luminar coated objective lens with stops 1, 2, 4, 8, 15(16), Text-figure 1A, F. This apparatus has a sturdy base and upright stand for rigid vertical orientation. The camera is mounted on a circular plate which is equipped with a ground glass screen to rotate interchangeably with the camera for focus and exposures. There is also a coupled screw focus arrangement, Text-figures 1D. A small simple wooden frame platform has been constructed with proper height to support the 9×9 inch plate glass, Text-figure 1G, which serves as the photography stage. This platform is held down firmly by weights. The entire apparatus is placed on two half-inch layer cushions of sponge rubber, Text-figure 1, U. S. Rubber "Ensolite" material, to minimize vibration. A small square of clear polaroid is placed in the system between the film and the objective lens. This can be placed loose on the camera mount bracket over the cir-



TEXT-FIG. *1*—Arrangement of equipment for photographing Foraminifera.

cular hole and the camera fitted securely over this. The polaroid sheet with its anisotrophy should have the proper orientation according to the reflected light off the specimen to eliminate the maximum amount of glare (diffused light) from striking the film. The plate glass stage gives little or no reflected light from the background of the field; hence a more effective blackness is produced in contrast to the illuminated specimen. Two high intensity Leitz low voltage Monla lamps are used for illumination. Each is 6 volts, 5 amperes, equipped with either a three-stage or continuous rheostat transformer. These are placed as close as possible to the specimen on opposite sides of the stage. The right lamp is set on intermediate step 6, and this is balanced in intensity with the lamp on the left side.The latter has variable control and can be made slightly brighter for shadow effect. Both lamps can be turned on and off with a single toggle switch. The aperture of the iris diaphragm is adjusted as small as possible for each light. Lighting is one of the most important variables and may take considerable manipulation to get the best results for each case. Adox KB-14 ultra-fine grain, thin emulsion, high resolution, black and white, medium speed panchromatic film is used in 36 exposure cartridges. This film can also be purchased in bulk. The next critical item is that of getting the best focus of the specimen. The camera mount bracket is adjusted so that the plane of the ground glass viewing screen (hence the film emulsion) is 22 cms. distance from the top surface of the glass plate stage. With the lens stop wide open (f/1) and the use of a magnifier on the ground glass screen, finer focus adjustment can be made by rotating screw mount, Text-figure 1D. Focus is obtained at a plane about one-half distance between the topmost surface on the specimen, and a horizontal plane whose intersection with the specimen gives a maximum surface area. In other words, everything below the latter plane will not be visible to the observer; consequently, it will form no image on the film. In order to get sharp pictures, it is necessary to have depth of field which will include everything between the median plane and the upper surface of the specimen. This can usually be accomplished if the fossil is not too large by getting the best focus as sharp as possible and stopping the lens down to the smallest opening (f/16). Normally such small amount of light for most film requires relatively long exposures, thus allowing for longer periods of vibration which will make the image fuzzy. In order to minimize this difficulty, the exposure time is cut down and results in an underexposed negative. A half second exposure is adequate for most specimens. Slightly longer exposures, 1 second or more,

should be used for small transparent or dark specimens which reflect less light. It is important for the underexposed negative to have a good sharp image which is a faithful reproduction of the fossil.

Development and printing.—The exposed film is developed with FR X-22 one shot concentrated fine grain developer. The developer is diluted according to the film, which in this case is Type 1 (Speed 25) high contrast. The film is underdeveloped 8 minutes instead of the recommended 13 minutes, and then fixed. The underexposed and underdeveloped negative is dried and will be restored to the correct density with an intensifier. Victor's fine grain intensifier no. 52 for under-developed negatives is used. This is diluted and filtered. The film negative is soaked in Kodak's Photo-Flo solution (wetting agent) before placing it in the intensifier. Intensification adds no grain and may be done in full light. The negative is immersed quickly in the solution. Intensification will proceed very rapidly, necessitating close watch and in most cases very short treatment, 5 or 10 seconds immersion often giving sufficient strength. The length of time in the intensifier will depend on the density of the negative image required. Strong intensification may change the color to yellowish-brown. This color gives better printing quality and is permanent and unobjectionable. Intensification strengthens detail brought out in developing where development was not carried far enough but it will not bring out detail which is not visible on the negative before intensification.

Light weight, smooth, glossy, contrast 2 or 3 bromide paper is excellent for enlargement work. To be assured of the best reproduction of photographs, glossy prints should be used; however, it is difficult to retouch such prints. Density inequalities on the negative from one exposure to another can be compensated for to some degree in the printing towards uniform tone in the prints.

The procedure is straightforward and might imply maximum results in minimum time; however, there are several variables which may cause variation in the results. Lighting is perhaps the most critical, for every specimen has its own rigid optimum requirements. This single factor calls for much trial and error manipulation. Some specimens photograph better with a single light.

The method has yielded satisfactory results and should encourage greater use of photographic reproduction for Paleozoic arenaceous Foraminifera.

REFERENCES

CUMMINGS, ROBERT H., 1956, Preparation of microfossils for photography: Micropaleontology, v. 2, p. 402.

FOURNIER, GEORGE, 1950, Photographing small Foraminifera: Micropaleontology, v. 4, p. 19–21.

——, 1954, Use of the pinhole diaphragm in photomicrography: Micropaleontology, v. 8, p. 58–62.

——, 1956, New Methods and techniques in the photography of microfossils: Micropaleontology, v. 2, p. 37–56.

——, 1957, Construction of pinhole diaphragm for use in photomicrography: Micropaleontology, v. 3, p. 85–87.

GUTSCHICK, RAYMOND C. & TRECKMAN, JOHN F., 1959, Arenaceous Foraminifera from the Rockford limestone of northern Indiana: Jour. Paleontology, v. 33, p. 229–250, pls. 33–37.

KUGLER, G., 1957, Preparation of microfossils for photography: Micropaleontology, v. 3, p. 190.

SANDER, N. J., 1955, An apparatus for photographing Foraminifera and other small objects: Micropaleontology, v. 1, p. 251–256.

TRIEBEL, E., 1947, Methodische und technischen Frage der Mikropalaontologie: Frankfurt on Main, Verlag Waldemar Kramer, 47 p., 35 text-figs. (Senckenberg. Naturf. Ges., Senckenberg-Buch 19).

STRATIGRAPHY AND PALEONTOLOGY OF AN OCCURRENCE OF DIATOMACEOUS EARTH IN NEBRASKA

JOHN D. BATES AND GEORGE BIEMESDERFER
Coastal Petroleum Company, Tallahassee, Florida, and
Bethlehem Steel Company, Bethlehem, Pennsylvania

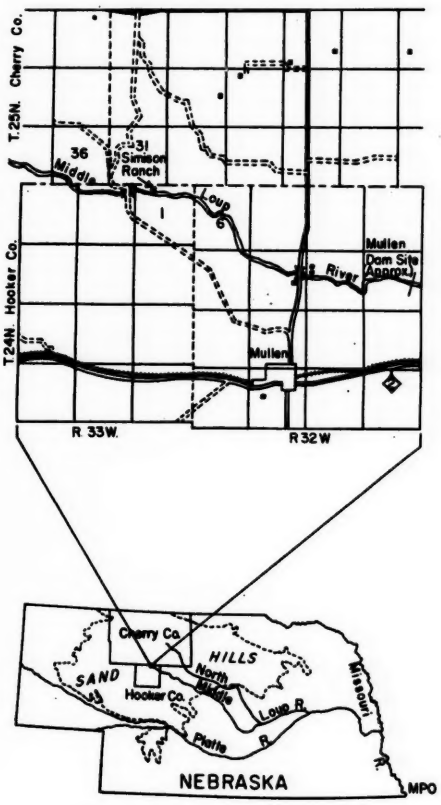
INTRODUCTION AND ACKNOWLEDGMENTS

Field work was carried on by the senior author during engineering-geological investigations on the potential Mullen Dam and Reservoir Site in the Middle Loup River Valley in Hooker and Cherry Counties, Nebraska (Text-fig. 1). This project was a water storage feature of the lower Platte River Development planned by the U. S. Department of the Interior, Bureau of Reclamation. Microscopic examination of the diatoms was done by the junior author in the geological laboratories of Franklin and Marshall College. Other organic remains were identified by Maxim K. Elias of the Nebraska Geological Survey. The purpose of this paper is to place on record a specific occurrence of diatomaceous earth in the proposed reservoir area. Publication is authorized by the Information Officer, Region 7, Bureau of Reclamation.

This reservoir site was located in the Sand Hills area of north-central and western Nebraska, a subdivision of the Great Plains Physiographical Province. The boundary of the Sand Hills area (Text-fig. 1) is after Condra, Reed & Gordon (1947, revised 1950). The sand hills form low rounded dunes, chiefly east to west in orientation, covering about one-fourth of the state of Nebraska. The dunes, except as exposed by wind blowouts, are covered with prairie grass, and the area is economically prominent in the production of range-land cattle.

Diatomaceous earth was reported in Nebraska by Barbour as early as 1903. Its occurrence was listed in nine counties, including Hooker County but not Cherry County, the two involved in the deposit described in this paper. It was stated that beds of diatomaceous earth had been found up to 6 feet in thickness in the state. Barbour explained the origin of the beds as "composed of silicious shells of microscopic seaweed, known as diatoms." He considered the beds Pleistocene in age due to their similarity to other diatom deposits of that age.

The writers wish to express appreciation for valuable suggestions and assistance to Paul L. Harley, Engineer of the Bureau of Reclamation; to Maxim K. Elias of the Nebraska Geological Survey; and to Harbans S. Puri, Florida Geological Survey. Grateful acknowledgement for editorial assistance is also made to Sankey L. Blanton, Jr., Geologist, Sun Oil Company.



TEXT-FIG. 1—Location map.

LOCALITY CONSIDERED

The dune sand is a relatively thin mantle (1–200 feet) over sandy "Loup River beds" (Pleistocene) and Ogallala (Pliocene) unconsolidated sediments. The "Loup River beds" as described by Lugn (1935) are exposed by the Middle Loup River and consist chiefly of soft white sandy marl and of firm medium to fine quartz sand. The diatomaceous earth was found in north-central Hooker County and south-central Cherry County in a layer exposed beside the river, stratigraphically near the base of these beds in the vicinity of Simison Ranch, 4.5 miles northwest of the village of Mullen (Text-fig. 1). It is exposed in a road cut near the county bridge on the south side of the river and was traced a third of a mile downstream and 1.5 miles upstream from that location, outcropping just above and on both sides of the river. The layer appeared to be 2 to 3 feet thick, approximately horizontal, gray in color, soft enough to be scratched by fingernail, and blocky but easily broken by a hammer. Hand samples are earthy in appearance, noncalcareous, light in weight, and when wet crumbled rapidly, and turned brown to black.

Microscopic examination of this material revealed a myriad of diatom valves and a very slight amount of impurity—probably one percent or less. The chief impurities are quartz grains and black organic material. The former were coated with a reddish-brown substance which is probably limonite or clay. The quartz grains, which floated free in the immersion media, were observed to be subangular to rounded in shape. Quartz grains also occurred in globules as nuclei surrounded by valve fragments. The globules appeared to be cemented together with an isotropic substance having the same index of refraction as the valves. Secondary deposition of siliceous cement apparently has occurred in the deposit.

The size of the quartz grains range from .125 to .003 mm. Diatom valves range in size from .02 to .002 mm. The index of refraction of the valves is about 1.44, similar to the index of some opal, as reported by Smith (1933).

Although much of the diatomaceous earth consists of valve fragments, sufficient complete specimens were floated free in the immersion media to permit the identification of several genera. No attempt was made to identify species. Most of the specimens belong to the Naviculineae, the largest family of the Class Bacillarieae. The following genera were observed: *Navicula*, *Pinnularia*, *Caloneis*, *Diploneis*, *Stauroneis*, *Amphipleura*, *Brebissonia*, *Melosira*, and *Cymbella*. *Melosira* and *Cymbella* are common in all bodies of water and in siliceous lake deposits, according to Ward & Whipple (1918).

In addition to the diatoms, the following remains were recognizable:

1. Siliceous sponge spicules—small broken monoxons. No further identification was possible due to fragmentary nature of these remains.
2. Fresh water snails—four small species were identified as described below.
3. Stems and leaves of a monocotyledonous herb, very fragmentary as described below.

The remains of snails were observed to be common in the diatomaceous earth but are not abundant. Their calcareous shells were invariably more or less etched, and their calcium carbonate has been partially dissolved apparently by water passing through the porous deposit. Because of this, the shells were very fragile and nearly always fell apart in fragments as soon as liberated from the matrix. On the other hand, their outer molds or impressions in the matrix occassionally were sufficiently distinct for an approximate identification of genera and species, usually with some corroborative evidence from adhered fragments of incompletely dissolved shell. Unfortunately it was the outer layer of shell that was usually dissolved quicker than the inner, which resulted in elimination of the denticulations in the aperture, the prominence and pattern of which are now used in specific and generic identifications. The identifications made, therefore, were preliminary as they were based only on size and shape of shells, and on the number and proportional height of volutions in them. The following four species of snails were thus identified:

1. *Gyraulus similaris* (Baker)
2. *Gyraulus* cf. *G. labiatus* (Leonard)
3. *Vertigo milium* (Gould)
4. *Gastrocopta procera* (Gould)

With the exception of *Gyraulus labiatus*, all these snails range throughout the Pleistocene and to the Recent. *G. labiatus*, however, is said by Leonard (1950) to be known from only the Yarmouth. Hence, if the shell truly belongs to this species, it would indicate that the diatomaceous earth bed is Yarmouth (interglacial stage between the Kansan and Illinoian glaciations) in age. Stratigraphically, it would thus be correlated with the Sappa Formation of eastern and southern Nebraska.

Ecologically, the identified snails are typical water loving forms. Species of *Gyraulus* "live in quiet waters, especially among plants, such as *Ceratophyllum* and other submerged vegetation," according to Leonard (1950). *Vertigo* lives only in moist environments among grasses and marshes and on pond borders, and *V. milium*, the smallest among known species of *Vertigo*, has not been found in the Great Plains Province, even under the most favorable conditions, Leonard states.

The remains of the monocotyledonous plant stems and leaves, though very fragmentary, were more abundant than the shells of the snails. The stem fragments were strongly impregnated by white silica. This has made them very fragile, but has enabled them to be preserved, even if broken into small pieces. From their shape, it may be concluded that the stem was more or less triangular in cross-section with the edges of the triangle rounded. This shape of stem suggests that the plant was a sedge, perhaps the common genus *Carex*. The stem was comparable in size to the submerged stem of the common living swamp sedge. *Carex lacustris* (Willd.), but it has more rounded edges. Its strong siliceous impregnation was, however, extremely different from the insignificant amount of silica in *C. lacustris*, and consequently it seemed to belong to a form no longer living, at least not in the Great Plains Region.

From his identification of the remains of the snails and of the vascular plant in the diatomaceous earth, Dr. Elias concluded that the material was deposited in a small lake or pond. The remains indicated ecologic conditions of life in or around this body of water which no longer exsit in the High Plains Region. They indicated a greater amount of moisture than at the present, and that this lake or pond was protected from drying out during the summer seasons.

To the authors' knowledge, the diatomaceous earth deposit has not been exploited commercially. Its extent perpendicular to the river is not known. While it was readily accessible at several points in the valley, the overburden increased rapidly and irregularly away from the river. Accessibility of the deposit was by sand hill trails only. The nearest rail point and highway were at the village of Mullen about 5 miles from the deposit.

REFERENCES

BARBOUR, H. E., 1903. Report of the state geologist: Nebraska Geol. Survey, Vol. 1.

CONDRA, G. E., REED, E. C. & GORDON, E. D., 1947, Rev. 1950, Correlation of the Pleistocene deposits of Nebraska: Nebraska Geol. Survey, Bull. 15A, fig. 1.

LEONARD, A. B., 1950, Univ. Kansas Paleont. Contrib., Mollusca. Art. 3, p. 19–20, pl. 3, fig. C.

LUGN, A. L., 1935, The Pleistocene geology of Nebraska: Nebraska Geol. Survey, Bull. 10, 2d ser., p. 189.

SMITH, GILBERT M., 1933, Fresh-water algae of the United States: McGraw-Hill.

WARD, HENRY BALDWIN & WHIPPLE, GEORGE CHANDLER, 1918, Fresh-water biology: John Wiley & Sons, Inc.

CHAETETES IN THE BIRD SPRING FORMATION NEAR LEE CANYON, CLARK COUNTY, NEVADA

MARK RICH

Department of Geology, University of North Dakota, Grand Forks

Chaetetes is generally found in rocks of Desmoinesian age in the midcontinent region. However, Dott (1954, 1955) considered it to be characteristic of Atokan age in the central Great Basin. He based his conclusions on the close association of *Chaetetes* with *Profusulinella* and *Fusulinella*. In the Ely Limestone of western Utah,

Hose & Repenning (1959) reported *Chaetetes* from about 100 to 300 feet below rocks containing microfossils which Henbest identified as being of probable Atokan age because of the presence of *Profusulinella?*.

Chaetetes was found by the present writer only 1085 feet and 1195 feet above the base of the thick section of the Bird Spring Formation (Mississippian-Pennsylvanian-Permian) north of Lee Canyon (center of the line between secs. 27 and 34, T. 17 S., R. 57 E., Charleston Peak quadrangle), Clark County, Nevada, and stratigraphically between beds containing *Profusulinella* and *Fusulinella*. Thus, the *Chaetetes*-bearing beds in the Cordilleran region extend into the southern Nevada area. Confirmation of Atokan age, however, must be based on relationship with fusulinids.

REFERENCES

DOTT, R. H., JR., 1954, *Chaetetes*, important marker in Pennsylvanian of central Great Basin (abstract): Geol. Soc. America, Bull., v. 65, p. 1245–1246.

——, 1955, Pennsylvanian stratigraphy of Elko and northern Diamond Ranges, northeastern Nevada: Am. Assoc. Petroleum Geologists, Bull., v. 39, p. 2211–2305.

HOSE, R. K., & REPENNING, C. A., 1959, Stratigraphy of Pennsylvanian, Permian, and lower Triassic rocks of Confusion Range, west central Utah: Am. Assoc. Petroleum Geologists, Bull., v. 43, p. 2167–2196.

OCCURRENCE OF VERTEBRATE REMAINS IN NEBRASKAN TILL OF NORTH-CENTRAL MISSOURI

LLOYD J. SCHMALTZ
Western Michigan University, Kalamazoo

In March, 1959, fragmentary vertebrate remains were found in Nebraskan till in north-central Missouri by Richard Ojakangas and Lloyd J. Schmaltz of the University of Missouri. These specimens are believed to be the first reported from Nebraskan till in Missouri. The fragments were identified by M. G. Mehl as representing the proximal end of the right femur of a Pleistocene horse which in size and other respects is the counterpart of what is generally designated *Equus complicatus* (University of Missouri, Dept. of Geology, Repository No. V. P. 671).

Several of the fragments were found in a silty-clay matrix within the unleached part of the till, and the remaining fragments were collected from the surface approximately four feet away. The entire exposure of drift, from bottom to top, includes Nebraskan till, Nebraskan gumbotil, and Kansan till. It is located on the south side of U. S. Highway 36 at the western city limits of Macon in the SW¼, NE¼, sec. 17, T. 57 N., R. 14 W., Macon County, Missouri.

AUTHORSHIP OF NAME *MESOLOBUS STRIATUS*

J. MARVIN WELLER
University of Chicago

In the March 1960 number of this JOURNAL, R. D. Hoare presented a description and discussion of "*Mesolobus striatus* Hoare, n. sp." (p. 222–223). This name was originally proposed by Weller & McGehee in 1933 (JOUR. PALEONTOLOGY, v. 7, p. 109–110). They dealt with the nomenclature of a well known Pennsylvanian brachiopod and the misinterpretations that had resulted from previous misunderstandings. Although they did not provide a formal description or figures, they characterized a species, that was without a valid name, in such a way that its distinguishing features were clearly recognizable. Also, they made reference to illustrations published by G. H. Girty but without a full citation.

No doubt this was not the best way to introduce a new specific name, and the description which Weller & McGehee promised was never published. Under these circumstances, Hoare has concluded that the name is a *nomen nudum*. This does not appear to be justified because there can be no doubt regarding the intention to name a new species that was characterized sufficiently to be recognized by all paleontologists who subsequently have been concerned with Lower Pennsylvanian faunas.

SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE THIRTY-FOURTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The thirty-fourth annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Rutland Room of Haddon Hall, Atlantic City, New Jersey, April 25–28, 1960, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

The Society's program consisted of papers on The Paleontological and Mineralogical Evidence for Polar Wandering and Continental Drift; Paleontology and Stratigraphy; and Sedimentary Mineralogy and Petrology.

At a joint session on Tuesday morning, April 26, Samuel P. Ellison, Jr., President of the S.E.P.M., presented the following address:

THINKING PATTERNS FOR GEOLOGISTS

Mr. Chairman, fellow members of the Society of Economic Paleontologists and Mineralogists, fellow members of the American Association of Petroleum Geologists, ladies and gentlemen, I propose to contribute to this program by presenting my views on how a geologist thinks. We have the power to improve and sharpen our geological wits if we will only understand the potential of our own system of thinking. We have no hesitancy in applying and accepting systems-engineering in practical industrial problems. Why should we not also accept, without hesitation, system in our own geological thinking?

My interest in the subject of thinking patterns is natural because of my employment in geological education. However, I intensified my concern on this matter after listening to a speech by Dr. Harry H. Ransom, Provost and Vice-President of the Main University, The University of Texas, when he addressed his faculty as follows: "In an age pre-occupied with outer space, the area still most important to education is that which lies between the human ears."[1]

[1] Ransom, Harry H., Feb. 1958, "Editorial," The Texas Quarterly, vol. 1, no. 1, Preface page. University of Texas Press, Austin, Texas.

The well-being and future progress of the geological profession are directly dependent upon the efficiency, alertness, sharpness and quantity of productive thinking that will go on in the space between our geological human ears. Every ton of ore, every pound of energy from fossil fuels and every gallon of ground water to be consumed by civilization in the future must first be a geological thought before it is a reality.

Geological thinking differs greatly from the thinking in other scientific disciplines because geology is mainly an observational science. It is impossible to bring the whole earth into the laboratory for a controlled experiment. Geological time cannot be reproduced in the laboratory and the geological clock cannot be turned back except through human imagination. Deductions, analogies and inferences based on observed data that are still in the process of being gathered are the backbone of many geological concepts. When experiments are set up to solve geological problems, the geologist finds himself overwhelmed with a continuously increasing interplay of complex factors as new data pour into the scene. The greatest virtue of geological thinking is the development of a disciplined continuous effort to seek new data, additional factors and alternative explanations. This is the life blood of geological activity.

The well known steps of the Scientific Method are the basic frame of reference for geological thinking patterns. Geologists, like all scientists, assemble and organize observed and experimental facts, interpret these facts and develop working hypotheses. Geologists use deductive and inductive thinking, devise experiments and make additional observations to test hypotheses and finally try to develop general natural laws. I have selected the following four categories as representing examples of typical geological thought patterns:

1. Data assembly and organization, si-

multaneously from multiple and complex sources.
2. Three dimensional thinking.
3. Time and sequence thinking.
4. Awareness of alternative interpretations.

Obviously, data assembly and organization is the first step in any scientific endeavor but the emphasis in geology is on gathering and organizing the facts from many complex sources simultaneously. Three-dimensional thinking and time and sequence thinking are distinctly geological and are applicable in all phases of the scientific method. Awareness of alternative interpretations remains a cardinal operating practice thoughout all steps of the scientific method.

DATA ASSEMBLY AND ORGANIZATION

Geologists bring together clues about rocks, minerals, fossils, stratigraphy and structure from every part of the earth's crust. Answers are obtained only after sifting great quantities of data. Good judgement and training will guide the worker in deciding what fragments of information are important on specific problems. A common geological task is the assembly of information on handy memory devices such as maps, logs and cross-sections. To assure himself of a thorough approach to a problem the geologist develops a flexible check list of sources of data. He performs somewhat like an airline pilot, who methodically checklists himself at every take-off and landing. The geologist differs from the airline pilot, however, in that he may expand or contract his check list as time and the economics of the situation dictate. It is not proposed that a geologist become a slave to a check list by mixing up his geological batter in accordance to a standard cook-book recipe. Instead, the geologist, always aware of the vast volumes of available data, will pick and choose the sources of information to fit within the limits of his budget and deadlines for completion of his maps and reports. The emphasis is to avoid the typical one-tract thinking patterns that so many of us are willing to follow because the path is easy.

A simple example of data assembly and organization is employed commonly in the gathering of information on a single exploration bore-hole. A well log has very little value unless the location, elevation, depths to lithologic and paleontologic key beds, and depths, thicknesses and patterns of lithologic and paleontologic units are immediately available. A subsurface geologist would not be caught with his elevation or location missing. He could do nothing about the structural picture of the well without depths to key beds. To make the well information useful he assembles on the log all of this data. The log strip then serves to hold the facts ready to be woven into a broader geological picture with other logs.

A complete information center may be constructed on a single log strip by assembly of several different logs such as self-potential curves, electrical resistivity curves, gamma ray curves, neutron ray curves, drilling time charts, caliper curves, lithologic logs, paleontologic logs, scout ticket information and engineering data. Karl A. Mygdal, geologist for the Pure Oil Company,[2] called these composite or executive logs.

Similarly it is common practice to construct composite or executive maps by combining structural, stratigraphic, lithofacies, thickness, geophysical, lease and ownership information on one plat. The map serves as an information center, analogous to a data processing machine which feeds back at a glance the whole picture for geological use. Many of us have failed to convince our executives to undertake a proposed exploration program because we failed to include on our logs or maps some vital bit of information. A flexible check-list designed to include this information would have saved the day for the exploration proposal.

Modern practice in the petroleum business employs the simultaneous assembly system in preparing for decisions on lease purchases, drilling deals and exploration programs. Management must have before it data from scouts, geologists, geophysicists, engineers, land men, legal council, pipeline experts, refiners and marketers before a final decision is made firm. Coordination and integration are words used to describe

[2] Mygdal, Karl A., May, 1948, Assemblage logs—Aid to management Petroleum Engineer, vol. 19, no. 8, pp. 242, 244, 247.

this activity but the basic idea is to obtain as much information as possible from as many pertinent sources as possible so the whole picture may be viewed at once.

Surprising as it may be the very purposes of the Society of Economic Paleontologists and Mineralogists are to promote the simultaneous assembly system of thinking. In Article II of the constitution of this society I quote: "The object of the Society shall be to promote the science of stratigraphy through research in paleontology and sedimentary petrology, especially as these relate to development of knowledge of the geology of petroleum."

There are hundreds of members of this society diligently engaged in seeking new knowledge and interpretations about the meanings of fossils, their stratigraphic distribution and environments. Few of these workers give significant attention to how much good information is being supplied about stratigraphy and environments of sedimentary rocks from the microscopes of the sedimentary petrologists. Likewise the sedimentary petrologists ignore completely how much data and new interpretations are being contributed by paleontologists. The fossils are as much a part of the sedimentary rock as the mineral grains. The very texture and composition of some rocks are controlled by fossils. Therefore, fossils must not be ignored. We ought to look forward immediately to the time when data from these two disciplines will be assembled simultaneously to give a more complete coordinated geological picture.

THREE-DIMENSIONAL THINKING

Most geological thinking involves three-dimensions. We advise prospective geology majors to take and pass an aptitude test to see whether they are capable of solving three-dimensional problems. Geologists are all aware of the importance of using their imagination to understand the positions of structure and stratigraphy in space. However, most of the data and interpretations are reduced to two-dimensional logs, maps, cross-sections and photographs. These two-dimensional flat pieces of paper are handy because they can be folded and filed for the purposes of clearing desk tops and keeping offices neat and trim.

Throughout our studies of rocks and minerals we try to understand the three-dimensional aspects of crystal structure, rock bodies and earth structure. Then, paradoxically, as advanced students we concentrate on petrology by studying thin-sections which are essentially two-dimensional. Seldom do we insist on thin sections taken in more than one direction from a single rock specimen.

In our effort to understand the three-dimensional factors of geology we invariably exaggerate the vertical scale. The fallacy of vertical exaggeration was forcibly demonstrated by Karl F. Dallmus when he gave his concepts on the shapes and origins of the sedimentary basins of the world. He showed that the floors of many basins were never deeper than would be allowed by the subtended chords of the earth's curved surface. This meant that many of our basins were really not concave saucer shaped features at all but rather convex shaped features with the floors less convex than the curvature of the earth.[3]

Scale models, peg models, stereograms and stereophotographs are required tools in any geological activity. Even though mining geologists and field geologists work in a three-dimensional conceptual environment, we ought to look forward to the time when the subsurface geologist, structural geologist, paleontologist, and petrologist will be surrounded with all kinds of aids to give three-dimensions to his work.

TIME AND SEQUENCE THINKING

Geology is the only discipline that stresses the importance of time. Geological concepts of time represent unique contributions to scientific thinking. Placing of geological events in their proper time position and perspective in the interpretation of earth history represents the goal of much geological thinking. A geologist who examines a rock, mineral or fossil specimen immediately tries to reconstruct the long history behind the specimen. The history includes the date and conditions of formation, and date

[3] Dallmus, Karl F., 1958, Mechanics of basin evolution and its relation to the habitat of oil in the basin. In *Habitat of Oil*, Spec. Publ. Am. Assoc. Petroleum Geologists, pp. 883–931.

conditions of lithification, date and number of times the specimen has been deformed, altered, and weathered. The geologist will try to read into the history the total sequence of events that have given the final product. He will recognize that the most recent events may mask or destroy evidence of earlier events.

Reconstruction of the sequence of events that shaped the rocks and minerals applies equally effective to the fluids in the earth. Robert F. Walters has shown how a reconstruction of geological history will permit us to trace the sloshing of fluids first in one direction, then another direction, back and forth, up and down, through permeable zones in the subsurface.[4] The final resting place of the various fluids, gas, oil and water is directly the result of the sequence of geological events in the particular region.

Paleogeographic, paleogeologic, palinspastic and paleotectonic maps are excellent ways to depict restored geological conditions for a particular geological date. These tools are not employed widely enough. Peg models of restored geology ought also be employed so that we could visulize three-dimensional geology for a particular time. Such restored three-dimensional models with the time factor incorporated would in a sense be four-dimensional.

AWARENESS OF ALTERNATIVE INTERPRETATIONS

For the past sixty-three years geologists have employed T. C. Chamberlin's method of multiple working hypotheses for working out interpretations that would account for given sets of geological facts.[5] Several working hypotheses are set up to explain a given group of facts. A search is made for additional data to prove or disprove each working hypothesis and finally a single hypothesis or some compromise combination hypothesis may be formulated to satisfy all of the conditions. Geologists now go a step further and show that even after exhaustion of all possible sources of data there still may remain two or more explanations for a given set of facts.

Ordinary electrical logs offer a simple example of how there may be two or more possible explanations for a given combination of electrical log curves. Assume that the electrical log shows a strong negative (to the left) self-potential curve indicating good permeability. Opposite the zone of permeability both shallow and deep penetrating resistivity curves show high resistivity readings (to the right). If the geologist does not examine his thinking closely and if he has no other data other than the electrical log he might say this zone contains oil. However, the same curves could be obtained from fresh water, gas, a cavern filled with drilling mud, or very very deep mud invasion. The log interpreter must always admit these alternative possibilities exist until other data from other sources give him a better answer.

Recently I have had the pleasure of examining acetic acid residues abundant with conodonts from the two feet of type locality surface exposures of the Chappel (Mississippian) limestone of central Texas. The conodonts from the Chappel have been given a great deal of study by W. H. Hass[6] from the United States Geological Survey. The facts are simple in that the Chappel limestone contains conodonts that are reported elsewhere from Lower Ordovician, Middle Devonian, Upper Devonian, Lower Mississippian, and Middle Mississippian. We can set up the following possible alternative interpretations to explain the age of Chappel formation conodonts:

A. Chappel faunas are Lower Mississippian with stratigraphic admixtures from below and stratigraphic leaks from above.
B. Chappel faunas are Middle Mississippian with stratigraphic admixtures from below.
C. Chappel faunas are transition from Lower Mississippian to Middle Mississippian with stratigraphic admixtures from below.
D. Chappel faunas are transition from Upper Devonian to Lower Mississippian with new age ranges for the fossils that seem to be out of place.
E. Chappel faunas are Lower Mississippian

[4] Walters, Robert F., 1958, Differential entrapment of oil and gas in Arbuckle dolomite of central Kansas,. Am. Assoc. Petroleum Geologists Bull., vol. 42, pp. 2133–2173.

[5] Chamberlin, T. C., 1897, The method of multiple working hypotheses, Jour. Geol. v. 5, pp. 837–848.

[6] Hass, W. H., 1959, Conodonts from the Chappel Limestone of Texas. U. S. Geol. Surv. Prof. Paper 294J, pp. 365–397, pls. 46–50.

with new age ranges for all fossils that seem to be out of place.

F. Chappel faunas are Middle Mississippian with new age ranges for all fossils that seem to be out of place.

G. Chappel limestone is zoned so that the bottom seven inches contain Lower Mississippian faunas with an admixture from below, and the top fourteen inches contain Middle Mississippian fauna.

Which of these possible choices will ultimately be correct depends upon additional field data and more assembly of information. There will undoubtedly also be additional alternative explanations.

CONCLUSIONS

In conclusion, I firmly believe that the geological profession could be greatly improved if each one of us would accept two challenges: first, searchingly re-examine and re-organize our own systematic thinking patterns to see if we are getting the best use of the space between our ears; and second, if we believe that our data assembly method, three dimensional thinking, time and sequence thinking, and awareness of alternative interpretations are all so good, we must advertize this to the world. Let the people know that we have a top flight product to offer and that we are solid contributors to scientific thinking.

No amount of group effort on our part to "certify" geologists or to form a professional registration system will substitute for vigorous and firm *individual* efforts to improve our lot.

Also at the joint session on Tuesday morning, President Ellison presented an honorary membership award to A. I. Levorsen. The award consists of a certificate and the receipt of both of our *Journals* for life.

Dr. Levorsen was born in Fergus Falls, Minnesota, on July 5, 1894. He graduated as a Mining Engineer from the University of Minnesota in 1917. After working in the Mid-Continent region for fifteen years in consulting capacities and as chief geologist for several oil companies, he shared in the discovery of the Fitts Pool in Southern Oklahoma in 1933. From 1945 until 1951, he was professor and dean of the School of Mineral Sciences at Stanford University. Dr. Levorsen's consulting work has included assignments in South America, Europe, India, Africa, and Australia. He is author of one of the most widely accepted petroleum texts used in our universities, that is, *Geology of Petroleum*. He is editor of many geological contributions, including several A.A.P.G. books.

President Ellison presenting Honorary membership scroll to A. I. Levorsen.

Levorsen is past president of The American Association of Petroleum Geologists, the Geological Society of America, and the American Geological Institute. His awards and recognitions are many—he is the possessor of the coveted Sydney Powers Memorial Medal which is the highest award granted by the A.A.P.G.; an honorary doctorate has been conferred on him by several institutions; and he was elected to honorary membership in the A.A.P.G. in 1958. Dr. Levorsen has been an active member of the S.E.P.M. for over twenty years.

Dr. John A. Wilson was the recipient of the award for a "Best Paper at the Convention." A two-volume book, *Mammals of North America*, was presented to him at the joint session, for his paper, "Stratigraphic Concepts in Vertebrate Paleontology," which was given at the 33rd Annual Meeting of the Society in Dallas, Texas, in 1959. His paper was judged, by a committee of five, on content, organization, originality, and presentation.

Now a professor of geology at the University of Texas, John A. Wilson was born November 3, 1914, in Lawrence, Massachusetts. His formal education was acquired at the University of Michigan where he was

President Ellison presenting book to John A. Wilson for best paper at 1959 Dallas Convention.

granted a B.A. degree in 1937 and a Ph.D. degree in 1941. Prior to joining the staff at the University of Texas in 1946, Dr. Wilson spent 2 years with the United States Naval Reserve and several years at the University of Idaho School of Mines as a teacher and a research geologist.

Professor Wilson's general field of interest is vertebrate geology. He has chosen the two-volume book, *Mammals of North America*, for his award. Dr. Wilson has published extensively, several papers having been accepted for publication in the *Journal of Paleontology* and *Bulletin* of the A.A.P.G.

Dr. Wilson is a member of The American Association of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists, Paleontological Society, Geological Society of America, and American Association for the Advancement of Science. He has participated in National Science Foundation High School Teacher training programs and High School Science enrichment programs. The American Philosophical Society awarded him a travel grant for study in Europe during the summer of 1958. He was recognized for outstanding teaching service to The University of Texas on Honors Day in March, 1953.

In addition to the above awards, Research Committee Chairman, Arthur C. Munyan, presented the Society's Award for the Best Paper for 1958 in the *Journal of Paleontology* to Mrs. Christina Lochman-Balk and James Lee Wilson, for their paper entitled, "Cambrian Biostratigraphy in North America," published in the March issue, Volume 32, Number 2. (Mrs. Balk was unable to be present and Dr. Wilson received her certificate for her.) Dr. Munyan also presented the award for the Best Paper for 1958 in the *Journal of Sedimentary Petrology* to Louis I. Briggs, for his paper entitled, "Evaporite Facies," published in the March issue, Volume 28, Number 1.

The Best Paper Awards are the sixth to be presented by the S.E.P.M. They consist of a certificate given to the author whose paper, appearing during the second preceding year, is judged by the Research Committee to be the most outstanding contribution of the year.

Born in Springfield, Illinois, on October 8, 1907, Mrs. Balk graduated from the Springfield High School in 1925 and in 1929 received a B.A. degree from Smith College (summa cum laude). After obtaining a M.A. degree from the same institution, she did graduate work at Johns Hopkins University

CHRISTINA LOCHMAN-BALK
Co-author of Best Paper in 1958
Journal of Paleontology.

receiving her Ph.D. degree in 1933. In 1934, Mrs. Balk was the recipient of a National Research Council grant for study of the Cambrian of Llano District, Texas. In 1959 she was awarded a National Science Foundation grant to describe the Upper Cambrian Faunas of the Deadwood formation, South Dakota.

From 1935 until 1947 Dr. Balk taught geology at Mount Holyoke College, advancing from instructor to associate professor. She has lectured in geology both at the University of Chicago and Johns Hopkins University. From 1955 until 1957, Mrs. Balk was stratigraphic geologist with the New Mexico Bureau of Mines and since 1957 has been a professor of geology at New Mexico Institute of Mining and Technology, Socorro, New Mexico.

In addition to her membership in the S.E.P.M., Dr. Balk is a member of Sigma Xi, American Association for the Advancement of Science, Paleontological Society, Geological Society of America, and New Mexico Geological Society.

Mrs. Balk was honored by the Society at its Annual Meeting in Los Angeles in 1958 for the best paper appearing in the 1956 *Journal of Paleontology*. The subject for this award was, "The Evolution of Some Upper Cambrian and Lower Ordovician Trilobite Families." published in Volume 30, Number 3.

President Ellison presenting certificate to James Lee Wilson for Best Paper in 1958 *Journal of Paleontology*, co-authored with Christina Lochman-Balk.

President Ellison presenting certificate to Louis I. Briggs for Best Paper in 1958 *Journal of Sedimentary Petrology*.

James Lee Wilson was born in Waxahachie, Texas, December 1, 1920. He attended the University of Texas where he received B.A. and M.A. degrees in 1942 and 1944. Yale University granted him a Doctor of Philosophy degree in 1949.

Dr Wilson was employed for 1 year by the Carter Oil Company as a field geologist, but upon graduation from Yale, he accepted a position with the University of Texas, teaching paleontology, stratigraphy, and field geology. Wilson left the University in 1952 to join Shell Development as a research geologist.

Mr Wilson's fields of interest are carbonate geology and Cambrian paleontology and stratigraphy. In addition to articles in the *Journal of Paleontology*, he has published, among others, in the *Bulletin* of The American Association of Petroleum Geologists and in the *American Journal of Science*.

In addition to S.E.P.M. membership, Dr. Wilson is a member of The American Association of Petroleum Geologists and the Paleontological Society. He is a fellow of the Geological Society of America and is currently serving on the S.E.P.M. Publications Committee.

Louis I. Briggs was born April 24, 1921, in Los Angeles, California. He attended

Fresno State College and received his Bachelor of Arts degree from that institution in 1943. He then continued his graduate work at the University of California at Berkeley from 1946–1950, receiving his Doctor of Philosophy degree in 1950.

From 1946–1950 Professor Briggs held the appointment of teaching assistant in geological sciences at the University of California. He had served in the U. S. Navy as a lieutenant in the Pacific Theatre from 1943 until 1946.

Dr. Briggs first came to The University of Michigan as an instructor in geology in 1950. Since coming to the University he has served as a concentration advisor for geology and as a counselor for the Unified Science Program. He presently has charge of the Subsurface Laboratory and Core Library.

Professor Briggs has published many articles on sedimentary petrology in the *G.S.A. Bulletin*, *Journal of Sedimentary Petrology*, *American Mineralogist*, *California Division of Mines Bulletin*, and others. He is a member of the Geological Society of America, American Association of Petroleum Geologists, American Geophysical Union, Association of Geology Teachers, and the Geochemical Society of America. He has been a member of the S.E.P.M. since 1951.

ANNUAL BUSINESS MEETING

The annual business session of the Society was called to order at 1:30 P.M., Tuesday, April 26, by Samuel P. Ellison, President, who introduced the officers for the new year as follows: President, William M. Furnish; Vice-President, Laurence L. Sloss; Secretary-Treasurer, John Imbrie; Editors of the *Journal of Paleontology*, M. L. Thompson and Charles W. Collinson; and Editor of the *Journal of Sedimentary Petrology*, Jack L. Hough.

It was moved, seconded, and carried that the minutes of the 1959 meeting be approved as published in the June, 1959, *Journal of Sedimentary Petrology* and the July, 1959 *Journal of Paleontology*.

The following reports were not presented at the Business Meeting, but instead they are printed in full below.

OUTGOING AND INCOMING SEPM COUNCIL

First Row—left to right: Gordon Rittenhouse, outgoing Past-President; Samuel P. Ellison, outgoing President; William M. Furnish, incoming President; Back Row, Left to right: John Imbrie, Secretary-Treasurer; L. L. Sloss, incoming Vice-President; William J. Plumley, outgoing Vice-President; Jack L. Hough, Editor of the *Journal of Sedimentary Petrology*; M. L. Thompson, Co-Editor of the *Journal of Paleontology*. Not shown in picture—Charles W. Collinson, Co-Editor of *Journal of Paleontology*.

1. *Report of the Editors of the Journal of Paleontology* (*M. L. Thompson and Charles Collinson*).—Volume 33 of the *Journal of Paleontology*, issued in conjunction with the Paleontological Society, contains 1139 pages of text and 133 numbered plates of fossil illustrations. The Society of Economic Paleontologists and Mineralogists' portion of the volume contains 528 pages of text and 53 plates of fossil illustrations, which represents an increase of 110 pages of text and 14 plates of fossil illustrations over that of the preceding year. Contributions cover a broad field of interest about like the preceding volume.

Fossils representing practically every major phylum of animals and some plants are discussed in this volume, including protozoans, sponges, molluscans, corals, brachiopods, bryozoans, graptolites, starfish, eurypterids, algae, rodents, and several groups of fossils of undetermined origins. One paper deals with a general fauna. Others concern ecology, invertebrate anatomy, and paleontologic techniques.

Contributions include thirty-two papers, fifteen paleontologic notes, and four reviews. Eleven papers concern larger types of fossil specimens, and eighteen concern what may be classified as microfossils. A stratigraphic summary of the thirty-two papers indicates that eighteen are of fossils of Paleozoic age, two are of fossils of Mesozoic age, and ten are of fossils of Cenozoic age. The others cannot be classified as to geologic age.

The number of contributions presented to the Journal of Paleontology for consideration has increased considerably during the past year. Unpublished manuscripts on hand are about half again greater than at this time last year.

The Illinois Geological Survey furnished secretarial, technical, and financial assistance.

2. *Report of the Editor of the Journal of Sedimentary Petrology* (*Jack L. Hough*).—*The Journal of Sedimentary Petrology* was published in 1959 as Volume 29, Numbers 1 through 4. The size of the Journal was again increased, this time from 148 pages per number to 160 pages per number, beginning with the June issue. A summary of the contents is given in the accompanying table. Despite the increase in size of the Journal, the supply of manuscripts awaiting publication has continued to increase during the year, so that there is again a delay in publication of 10 or 11 months for manuscripts currently received.

The national origins of the articles, notes, and discussions of Volume 29 were as follows:

United States	51
England and Wales	7
Canada	3
Australia	3
India	2
New Zealand	1
Japan	1
Denmark	1
Norway	1

Dr. Frederick W. Cropp, of the University of Illinois staff, was appointed Managing Editor in September, to assist with the increased work of editing the Journal.

As in the past ten years, the University of Illinois has provided the services of the Editor and of a part-time student editorial assistant.

3. *Report of the Secretary-Treasurer* (*John Imbrie*).—Net income for the year ended December 31, 1959, was $3,868. This com-

Journal of Sedimentary Petrology, Vol. 29, 1959

	Articles		Notes		Discussions		Reviews		S.E.P.M. Data[1]	Advertising[2]	Other[3]	Total
	No.	Pages	No.	Pages	No.	Pages	No.	Pages	Pages	Pages	Pages	Pages
1. (Mar.)	13	111	1	2	1	1	2	3	21	2	8	148
2. (June)	16	128	3	6	—	—	1	1	21	3	5	164
3. (Sept.)	17	147	3	6	—	—	—	—	—	1	6	160
4. (Dec.)	13	142	2	3	—	—	—	—	—	2	13	160
Total	59	528	9	17	1	1	3	4	42	8	32	632

[1] Including membership list (March) and minutes of Annual Meeting (June).
[2] Exclusive of advertisements on covers.
[3] "Other" includes title pages, index, errata, and miscellaneous announcements.

pares with $5,883 for the preceding year, a drop of $2,015. This drop reflects the fact that, while our total income (including dues, subscriptions, sales of special publications and back numbers, and income from other sources) has increased $6,993, our total costs and expenses have increased $9,008. Disregarding inventory changes, the total increase in expenses to be accounted for is $8,025. Of this amount, $3,426 is due to the difference between the cost of printing *Silica in Sediments* and the cost of printing the *Journal of Sedimentary Petrology Index* the previous year. The balance is due to an increase in printing costs for the two journals ($3,302) and to an increase in administrative expenses ($1,297), chiefly salaries (up almost $500) and postage (up almost $400).

Only one special publication is operating at a financial loss, the *Journal of Sedimentary Petrology Index. Silica in Sediments* paid for itself in only nine months, and is now in the profit column.

To summarize the financial side of the picture, it is clear that the position of the Society remains a strong one. In particular, we may feel satisfaction from the fact that this position has been maintained in the face of rising costs. The success of our financial operations can be attributed, first, to the fact that the Society, through its publication program and in other ways, continues to serve the profession and to play a unique and valuable role; and, second, to the skill and imagination exercised by our headquarters staff and by our editors.

As regards membership, the Society continues to show a modest but progressive increase. As of December 31, 1959, our rolls include a total of 1530 members, including 1134 active members, 384 associates, 6 correspondents, and 6 honorary members. This total reflects a net gain of 74 over the previous year. Viewed as a percentage increase (0.5%) this growth rate is essentially the same as the Society has maintained since 1956. It is interesting to note that A.A.P.G. membership figures show about the same rate of increase for this period, and that the percentage of A.A.P.G. members belonging to S.E.P.M. has remained steady

(*Continued on page 775*)

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	Dec. 31, 1959	*Dec. 31, 1958*	*Dec. 31, 1957*
1. S.E.P.M. Membership:			
Active Members	1134	1094	1085
Associates	384	351	319
Correspondents	6	6	6
Honorary Members	6	5	3
	1530	1456	1413
2. *Journal of Paleontology* Mailing List:			
S.E.P.M. Active & Honorary Members	509	503	528
S.E.P.M. Associates	173	167	160
Subscribers	962	912	840
P.S. Members	699	649	638
	2343	2231	2166
3. *Journal of Sedimentary Petrology* Mailing List:			
S.E.P.M. Active & Honorary Members	775	726	721
S.E.P.M. Associates	261	220	207
S.E.P.M. Correspondents	6	6	6
S.E.P.M. Subscribers	1076	997	979
	2118	1949	1913
4. Edition of *Journal of Paleontology*	2500	2500	2400
5. Edition of *Journal of Sedimentary Petrology*	2600	2500	2400
6. Number of pages, *Journal of Paleontology*	1139	1170	1190
7. Number of plates, *Journal of Paleontology*	133	148	150
8. Number of pages, *Journal of Sedimentary Petrology*	632	528	484
9. New Members	153	125	150
10. Transfers to active membership	32	24	49
11. Members and associates dropped for non-payment of dues (1/1/60)	43	65	49

REPORT OF CERTIFIED PUBLIC ACCOUNTANTS

The Council, Society of Economic Paleontologists and Mineralogists:

We have examined the accompanying balance sheet of the Society of Economic Paleontologists and Mineralogists at December 31, 1959, and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the statements mentioned above present fairly the financial position of the Society of Economic Paleontologists and Mineralogists at December 31, 1959, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

ARTHUR YOUNG & COMPANY

Tulsa, Oklahoma, January 18, 1960

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
BALANCE SHEET, DECEMBER 31, 1959

ASSETS

	Total	*General Fund*	*Publication Fund*
CURRENT ASSETS:			
Cash	$40,763.71	$31,220.83	$ 9,542.88
Savings account	3,919.64	3,919.64	—
Accounts receivable	442.52	359.52	83.00
Total current assets	$45,125.87	$35,499.99	$ 9,625.88
PUBLICATIONS:			
Journal of Paleontology:			
Issues prior to 1959—10,078 journals at $0.50 each (1,541 complete volumes)	$ 5,039.00	$ 5,039.00	$ —
Issues 1 to 6 of 1959—773 journals, at cost	1,523.36	1,523.36	—
Reprints in 1948, Volume 1, 1927—633 volumes, at cost	1,375.39	1,375.39	—
Journal of Sedimentary Petrology:			
Issues prior to 1959—5,300 journals at $0.50 each (1,405 complete volumes)	2,650.00	2,650.00	—
Issues 1 to 4 of 1959—1,480 journals, at cost	1,870.83	1,870.83	—
Special publications, at cost:			
Turbidity Currents, 31 copies	26.51	—	26.51
Recent Marine Sediments, 246 copies	507.62	—	507.62
Finding Ancient Shorelines, 21 copies	36.70	—	36.70
Regional Aspects of Carbonate Deposition, 86 copies	191.99	—	191.99
Journal of Sedimentary Petrology Index, 1,312 copies	757.42	—	757.42
Silica in Sediments, 993 copies	2,192.54	—	2,192.54
Total publications	$16,171.36	$12,458.58	$ 3,712.78
FURNITURE AND FIXTURES (less reserve, $1,793.84)	$ 1.00	$ 1.00	$ —
DEFERRED CHARGES	$ 2,864.84	$ 2,168.84	$ 696.00
	$64,163.07	$50,128.41	$14,034.66

LIABILITIES AND SURPLUS

CURRENT LIABILITIES:			
Accounts payable	$ 4,382.08	$ 4,377.08	$ 5.00
Amount payable to Paleontological Society	4,086.02	4,086.02	—
Total current liabilities	$ 8,468.10	$ 8,463.10	$ 5.00
DEFERRED CREDITS:			
Subscriptions to journals—net of portion to be received by Paleontological Society	$12,203.35	$12,203.35	$ —
Membership dues for 1960	$10,286.00	$10,286.00	$ —
Total deferred credits	$22,489.35	$22,489.35	$ —
SURPLUS	$33,205.62	$19,175.96	$14,029.66
	$64,163.07	$50,128.41	$14,034.66

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
STATEMENT OF INCOME AND SURPLUS
YEAR ENDED DECEMBER 31, 1959

	Total	General Fund	Publication Fund
INCOME:			
Membership dues and subscriptions:			
Journals of Paleontology and Sedimentary Petrology	$ 4,947.00	$ 4,947.00	$ —
Journal of Paleontology	17,600.02	17,600.02	—
Journal of Sedimentary Petrology	14,471.44	14,471.44	—
	$37,018.46	$37,018.46	$ —
Sales of special publications:			
Turbidity Currents	$ 197.25	$ —	$ 197.25
Recent Marine Sediments	998.00	—	998.00
Finding Ancient Shorelines	148.90	—	148.90
Regional Aspects of Carbonate Deposition	891.50	—	891.50
Journal of Sedimentary Petrology Index	242.00	—	242.00
Silica in Sediments	4,629.00	—	4,629.00
	$ 7,106.65	$ —	$ 7,106.65
Sales of back numbers:			
Journal of Paleontology	$ 4,579.35	$ 4,579.35	$ —
Journal of Sedimentary Petrology	1,517.95	1,517.95	—
	$ 6,097.30	$ 6,097.30	$ —
Sales of plates	$ 569.30	$ 569.30	$ —
Advertising	$ 433.20	$ 433.20	$ —
Donation from The American Association of Petroleum Geologists	$ 2,040.00	$ 2,040.00	$ —
Miscellaneous	$ 429.36	$ 429.36	$ —
	$53,694.27	$46,587.62	$ 7,106.65
Less portion of 1959 income accrued to Paleontological Society	$ 3,270.22	$ 3,270.22	$ —
INCOME	$50,424.05	$43,317.40	$ 7,106.65
COSTS AND EXPENSES:			
Cost of printing:			
Journal of Paleontology	$13,681.56	$13,681.56	$ —
Journal of Sedimentary Petrology	12,187.36	12,187.36	—
Silica in Sediments	4,605.89	—	4,605.89
	$30,474.81	$25,868.92	$ 4,605.89
Expenses:			
Clerical salaries	$ 8,235.00	$ 8,235.00	$ —
Office supplies	501.81	501.81	—
Postage and express	1,992.55	1,992.55	—
Office rent	2,000.00	2,000.00	—
Telephone	72.16	72.16	—
Audit fee	215.74	215.74	—
Payroll taxes	197.84	197.84	—
Miscellaneous	2,361.80	2,050.55	311.25
	$15,576.90	$15,265.65	$ 311.25
Adjustment for (increase) decrease in inventory of publications	$ 504.21	$ 1,424.39	$ (920.18)
	$46,555.92	$42,558.96	$ 3,996.96
NET INCOME	$ 3,868.13	$ 758.44	$ 3,109.69
SURPLUS AT DECEMBER 31, 1958	29,337.49	18,417.52	10,919.97
SURPLUS AT DECEMBER 31, 1959	$33,205.62	$19,175.96	$14,029.66

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
NOTE TO FINANCIAL STATEMENTS
DECEMBER 31, 1959

It is the opinion of counsel that the Society, as a division of The American Association of Petroleum Geologists, is exempt from federal income tax under provisions of Section 501(c) of the Internal Revenue Code, except to the extent of "unrelated business income." The Society, based on the opinion of counsel, has taken the position that none of its income is "unrelated business income" within the provisions of Section 512 of the Internal Revenue Code and therefore no liability has been provided for federal and state income taxes in the financial statements.

(*Continued from page 772*)

at about 7.5. This is somewhat surprising in view of the increased attention paid in recent years to the field of research represented by our Society.

It is with sincere regret that we report the death of the following members during 1959:

Francesco Cipolla
Alexander Deussen
Charles R. Fettke
W. D. Kleinpell
Walter C. Toepelman

4. *Report of the Research Committee* (*Arthur C. Munyan, Chairman*).—Membership of this Committee is:

1960	*1961*	*1962*
H. A. Ireland	Heinz Lowenstam	Eduardo Guzman
Grover E. Murray	W. H. Akers	R. H. Schweers
W. D. Pye	Phil W. Reinhart	M. L. Natland
L. M. Cline	F. B. Van Houten	H. N. Frenzel
S. G. Wissler	A. C. Munyan	R. N. Ginsburg

The Committee, at its annual meeting in Los Angeles on March 10, 1958, selected the topic "Paleontological and Mineralogical Aspects of Polar Wandering and Continental Drift" for a symposium to be presented in 1960 at Atlantic City. Co-chairmen W. C. Gussow and Gordon Rittenhouse contributed much time and effort to selecting speakers and to moderating the symposium sessions. The completed program was as follows:

Session I

Presiding:
Arthur C. Munyan, Chairman of Research Committee.
Wm. C. Gussow, Union Oil Company, Calgary, Alberta.

S. W. Carey (University of Tasmania, Hobart, Tasmania) Tectonic Approach to the Problem of the Dispersion of the Continents.

Warren Hamilton (U. S. Geological Survey, Denver, Colorado) Antarctic Tectonics and Continental Drift.

H. J. Harrington (Tennessee Gas Transmission Co., Houston, Texas), Deep Focus Earthquakes in South America and their Possible Relation to Continental Drift.

S. K. Runcorn (King's College, Newcastle Upon Tyne, 1, England), Paleomagnetism and Relative Movements of the Poles and Continents.

B. W. Wilson (Shell Development Company, Houston, Texas), Measurement of Rock Magnetism in Sandstone Samples.

E. R. Deutsch (Imperial Oil Limited, Calgary, Alberta), Polar Wandering and Continental Drift: An Evaluation of Recent Evidence.

B. C. Heezen (Lamont Geological Observatory, Palisades, New York), Deep Sea Topography.

G. W. Bain (Amherst College, Amherst, Massachusetts), Climatic Zoning During the Geologic Past.

Session II

Presiding:
Gordon Rittenhouse, Shell Development Company, Houston, Texas.
Arthur C. Munyan, Chairman Research Committee.

Ting Ying H. Ma (Taipei, Taiwan), Continental Drift and the Sudden Displacement of the Solid Earth over the Liquid Core.

K. E. Caster (University of Cincinnati, Cincinnati, Ohio), The Meaning of Austral Siluro-Devonian Realms.

S. C. Nordeng (Michigan College of Mining and Technology, Houghton, Michigan), Pre-cambrian Stromatolites as Indicators of Polar Shift.

A. G. Fischer (Princeton University, Princeton, New Jersey) Distribution and Growth Patterns of Silurian Tabulate Corals Compared to Three Paleogeographic Hypotheses.

Maurice Ewing (Lamont Geological Observatory, Palisades, New York), Theories of Glaciation and Ice Age Formation.

Wm. C. Gussow (Union Oil Co. of California, Calgary, Alberta), Metastasy.

C. R. Longwell (c/o U.S.G.S., Menlo Park, California), General Comments on the Problems of Polar Wandering and Continental Drift.

The Committee, polled during 1959 to nominate an Honorary Member, overwhelmingly recommended A. I. Levorsen to the council for election. President Ellison notified Dr. Levorsen of his election by council.

Another poll of the Committee resulted in selection of two possible Correspondents, but council action was deferred because of time. The names will be referred to the incoming committee for future action.

The best paper in the *Journal of Sedimentary Petrology* for 1958, selected by the Committee, was determined to be that by Louis I. Briggs entitled *Evaporite Facies*, March, 1958. The best paper in the *Journal of Paleontology* for 1958 was chosen as that by Christina Lochman Balk and James Lee Wilson entitled *Cambrian Biostratigraphy in North America*, March, 1958. The awards for these papers were presented to the authors at the annual meeting in Atlantic City.

5. *Report of the Publications Committee (H. A. Ireland, Chairman).*—The Publications Committee of the S.E.P.M. is composed of H. A. Ireland, Chairman, J. L. Wilson, C. L. Cooper, Tjeerd van Andel, and A. C. Munyan as Chairman of the Research Committee. Terms of the first two named, continue into 1961 and the other three expire in 1960. The new Chairman of the Research Committee automatically becomes a member.

The principal action taken by the Committee was on the publication of the symposium on Concepts of Stratigraphic Classification and Correlation presented at the Dallas meeting in March, 1959. After much discussion at the Dallas meeting and subsequent correspondence it was decided not to recommend publication of the symposium and a report of the reasons was made to the Council for final consideration and action.

A paper by M. S. Rosenfeld and J. L. Fitch on Rapid Chemical Analysis of Sedimentary Rocks was submitted by the President for examination as a possible special publication. The paper was excellent, but it was decided that there would be insufficient demand to justify the cost of publication. It was recommended as a publication for the *Journal of Sedimentary Petrology* with a condensation of the tables and other appended matter.

An agreement was recommended and passed by the Council to extend purchase of S.E.P.M. publications at member prices to all members of the Geological Society of America and that the G.S.A. would extend similar price reductions of their publications to members of the S.E.P.M. R. C. Moore, President of the Geological Society of America, was notified of the action for their approval.

6. *Report on the Earth Sciences Division of the National Research Council (John C. Frye, S.E.P.M. Representative.)*—The Division of Earth Sciences, in keeping with its primary objective, rendered service to federal agencies and technical and scientific groups. These services were rendered through twelve advisory committees ranging from Arctic Sea ice to atomic waste disposal, and five technical committees. The technical committees include AMSOC (feasibility of drilling through the crust of the earth), Clay Minerals, Glacial Map of the United States East of the Rockies, National Atlas of the United States, and Topographic Maps Illustrating Cultural Geography. In addition, the American Geological Institute and the Advisory Board on education operate through the facilities of the Academy-Council.

The annual meeting of the Division was held on March 20, 1959, during the joint annual meeting of the Research Council, and was attended by the S.E.P.M. representative. This was the second year in which all divisions met simultaneously in Washington with opportunity for general sessions of the entire Council. Topics discussed at the general sessions of the Council included: "The nature and conduct of fellowship programs in science," "U. S. science in foreign aid," "Means and patterns for the support of scientific research," and others.

At the annual meeting of the Earth Sciences Division the following items, published during the year as a result of divisional activities, were presented.

Thermal Considerations in Deep Disposal of Radioactive Wastes, by Francis Birch, NAS-NRC Pub. 588, July 1958

Annual Report of the Division of Geology and Geography, 1946–1947 (October 1958)

Annual Report of the Division of Earth Sciences, 1957–1958, (October 1958)

A Regional Geography of Iceland, by Vincent H. Malmstrom, NAS-NRC Pub. 584, April 1958

The Political Geography of Burgenland by Andrew F. Burghardt, NAS-NRC Pub. 587, June 1958

Indigenous Tropical Agriculture in Central America, by Craig L. Dozier, NAS-NRC Pub. 594, October 1958

Geography of Food Supply in Central Minas Gerais, by Kempton E. Webb, NAS-NRC Pub. 642, January 1959.

Physical and Chemical Properties of Sea Water, Proceedings of a conference held at Easton, Md., September 4–5, 1958, NAS-NRC Pub. 600, March 1959.

Oceanography 1960–1970, Chapter I: Introduction and Summary of Recommendations, by Committee on Oceanography, March 1959

Clays and Clay Minerals, Proceedings of the Fifth National Conference. held at Urbana, Ill., October 8–10, 1956, NAS-NRC Pub. 566, 1958

Guidebook for field excursion to northeastern Maryland and northern Delaware, Seventh National Conference on Clay Minerals, Washington, D. C., October 20–23, 1958.

Preliminary steps were taken toward the organization of a joint committee by the

Divisions of Earth Sciences and Anthropology to deal with representation at the International Congress of Quaternary Research to be held in Poland during 1961, and a possible invitation to the Congress to meet in the United States during 1965.

The Committee on the Glacial Map of the United States East of the Rockies completed its work during the previous year, and the resulting map was published by the Geological Society of America. The Committee on Clay Minerals held its eighth annual conference at the University of Oklahoma in October, 1959, and the 1960 meeting is scheduled for Purdue University, Lafayette, Indiana. The Advisory Screening Committee on Fulbright Awards for Geology was active during the year and a proposal has been made to the Organizing Committee of the XXI International Geological Congress that there be a session devoted to describing the various exchange programs.

The annual conference sponsored by the Division of Earth Sciences, held in Washington, D. C., on May 2, 1959, was attended by the S.E.P.M. representative. The subject for informal discussion was the Atomic Energy Commission's "Project Plowshare" which is concerned with the non-military uses of nuclear explosives.

7. *Report on the American Geological Institute* (*Gordon Rittenhouse*).—Your senior representative attended the AGI Board of Directors meeting in Dallas, but was unable to attend in Pittsburgh. As reported last year, AGI finances are a critical problem, and have led to the appointment of a committee, B. W. Beebe, chairman, to consider reorganization of AGI. This committee has been extremely active and is expected to submit proposals for reorganization at the time of the AAPG-SEPM meeting in Atlantic City. The problems facing AGI and the need for a new look at the future of this organization were presented by President R. C. Moore, in the January-February, 1960 issue of "GeoTimes."

8. *Report of the S. E. P. M. Representative to the A.G.I. Government Relations Committee* (*Norman S. Hinchey*).—The A.G.I. Government Relations Committee met on March 31 and November 2, 1959. Among matters considered were: the need for a government relations committee, the membership of the committee, a program of responsibilities of the committee and a current study of government influences on the earth sciences. It was recommended that the Executive Committee of A.G.I. participate, with the Chairman of the G. R. Committee and the Executive Director of A.G.I., in implementing the attempt of the G. R. Committee to provide leadership and direction of that committee's efforts.

9. *Report of the Permian Basin Section* (*Carl Ulvog*).—The fifth annual meeting of our section is being planned for April 14, 1960, at Abilene, Texas. Registration is scheduled to begin the afternoon of April 13th at meeting headquarters, The Windsor Hotel. Mr. James K. Munn of Pan American Petroleum Corporation is general chairman and Dr. John P. Brand of Texas Technological College is in charge of the one-day technical program.

A field conference on the central part of the Bend Arch will follow the technical program and business meeting, being slated for April 15 and 16. Registration for the field trip will be accepted on April 13 and 15 at meeting headquarters in Abilene. Mr. Thomas Hambleton of Texaco is general chairman of the field meet. Exposures of lower Permian and Pennsylvanian rocks will be studied under the general leadership of Mr. Leonard F. Brown of the Bureau of Economic Geology.

Officers elected for the 1959-1960 term are: Carl Ulvog, President; Thomas Hambleton, 1st Vice-President; John P. Brand, 2nd Vice-President; Raymond W. Rall, Secretary; and Charles A. Reinke, Treasurer. Voting for the 1960-1961 officers will not be concluded until March 1, 1960; thus the new executive committee cannot be named at this writing.

Membership in our Section now totals 202, of which 190 reside in the Permian Basin area.

10. *Report of the Gulf Coast Section* (*David E. Pope*).—Under the leadership of President Marcus A. Hanna, the Gulf Coast Section was very active during the past year, 1958–59, in the ventures enumerated below.

On May 2, 1959, a field trip was conducted jointly with the Houston Geological Society. This trip, "Lower Tertiary and Upper Cretaceous of Brazos River Valley, Texas," continued the study of the central

Texas Brazos River section, the upper portion of which was covered by the December 6, 1958, field trip of the Gulf Coast Section and the Houston Geological Society. The field trip committee again consisted of E.H. Rainwater, chairman, C. W. Stuckey, Jr., H. G. Schoenike, H. B. Stenzel, and L. J. Vittrup; and, Fred E. Smith, Professor of Geology at Texas A. & M. College, was again the field trip leader. He, assisted by several others, compiled an excellent guidebook for the trip. C. W. Stuckey, Jr. and E. H. Rainwater also joined in describing the geologic section and history of the localities visited. Marcus A. Hanna contributed by studying the outcrops and explaining the probable origin of the sedimentation and structural features exposed. Many other individuals assisted with this 90-odd mile trip, which was attended by more than 150 geologists.

The annual meeting of the Section was held in Houston, Texas, November 11–13, in co-operation with the Gulf Coast Association of Geological Societies. This convention was designated as the 1959 fall regional meeting of the American Association of Petroleum Geologists. Several members of the Section contributed to the program, especially to the portion of it devoted to the symposium for the field trip which followed the convention. Several members also acted as presiding co-chairmen for some of the technical sessions. These included Olin G. Bell and M. A. Hanna who served in this capacity for the opening session. The former was general chairman of the convention committees.

The annual business meeting was held November 12 after the technical sessions of that day. President Hanna asked for reports from the officers and committee chairmen; and, several projects of the section were discussed. The President thanked his officers, editor, and members for their co-operation during the year, and introduced the newly elected officers. The incoming president made a few brief remarks after which the meeting was adjourned.

"Recent Sediments of the North-Central Gulf Coastal Plain" was the subject of investigation for the field trip of November 14 and 15, 1959. This trip was routed along the coastal area from the western tip of Galveston Island, Texas, eastward to the vicinity of Creole, Louisiana. It was an extension of the field trip of October 30–November 1, 1958, "Sedimentology of South Texas," and was conducted jointly with the Gulf Coast Association of Geological Societies. The field trip committee consisted of H. R. Gould, chairman, H. A. Bernard, Marcus A. Hanna, Henry E. Kane, R. J. LeBlanc, and E. McFarlan, Jr. Initial planning of the trip was assisted by M. A. Hanna, H. N. Fisk, and T. D. Cook. All members of the field trip committee served as commentators in the field and contributed material used in preparation of the excellent guidebook. Several others also assisted in the field and presented papers for the preceding symposium. Approximately 100 attended this field trip. Guidebooks for this trip and the one discussed above can be obtained through the Houston Geological Society.

11. *Report of the Pacific Coast Section (Weldon W. Rau).*—The Pacific Section has an active paid-up membership of 161, and a balance in the treasury of $1,765.51. President of the Section is Weldon W. Rau and secretary-treasurer is Richard L. Brooks.

This year, National and Pacific Section S.E.P.M. membership awards and subscriptions to both journals were granted to sixteen students from various Pacific Coast colleges and universities. The faculty of the paleontology or geology department of each school nominated the student to receive the award.

The monthly Biostratigraphy Seminar, sponsored jointly by the Pacific Section S.E.P.M. and the Bakersfield College is in progress. Eight papers by distinguished research workers from the West Coast, covering the field of stratigraphy, paleontology, and ecology are being presented. Mr. Richard Pierce is chairman, and the average attendance at the meetings is approximately fifty.

The S.E.P.M. Pacific Section will sponsor their annual dinner meeting and field trip on April 15 and 16. Dr. Alfred Loeblich is chairman of the event. The geology and paleontology of rocks of Cretaceous age will be studied in the vicinity of the Panoche Hills, California. The Friday evening dinner meeting will be held at the Hacienda in Fresno, California. Mr. Max Payne will present a paper on the stratigraphy of the

Panoche Hills. He will also lead the field trip on the following day.

The Pacific Section S.E.P.M. will again cooperate with the A.A.P.G. and S.E.G. in putting on the thirty-seventh annual fall meeting at Los Angeles on November 3 and 4. A two-day technical session and dinner meeting are being planned by Dr. Alfred Loeblich, program chairman.

A dinner dance will be held in December which is co-sponsored by the S.E.P.M., A.A.P.G., and S.E.G.

12. *Report of the S.E.P.M. Delegate to the IX International Botanical Congress Montreal, Quebec, August, 1959 (Alfred Traverse).*—Largely because of the interest of economic micropaleontologists in fossil plant nomenclature—especially that of fossil pollen and spores—S.E.P.M. appointed a delegate to the IX International Botanical Congress, held in Montreal in August of 1959. Mostly as a result of the mushrooming volume of publication on fossil pollen and spores interest in paleobotanical nomenclature and its position in the International Code of Botanical Nomenclature ran relatively high prior to and during the Montreal congress.

About fifty proposals to amend paleobotanical provisions of the Code were published by paleobotanists (including paleopalynologists) before the Congress. These were rather fully discussed, both in print and at several symposia on nomenclature, in the years between the Paris VIII International Botanical Congress (1954) and the Montreal meeting. The proposals ranged from radical ones tending toward creation of a separate code for fossil pollen and spores, to conservative ones aimed at eliminating obvious errors of language in the Code adopted at Paris in 1954.

The results of the deliberations of the Committee for Paleobotanical Nomenclature at Montreal were accepted nearly *in toto* by the Bureau of Nomenclature, and by the Congress as a whole. These results were fundamentally conservative. Not only were proposals to create special status for fossil pollen and spores rejected, but even the existing separate paleobotanical appendix in the Paris 1954 and earlier codes was eliminated. In the Code adopted at Montreal it is, therefore, emphasized that fossil pollen and spores are amenable to the same sort of nomenclatural treatment as are other categories of plant fossils and are not to be thought of as being slightly beyond the pale. Furthermore, the abolition of the erstwhile paleobotanical appendix, as well as adoption of several specific emendations of the rules, emphasized that all specimens of fossil plants are to be handled as representating taxa of plants. Several emendations were directly aimed at eliminating any possible doubt about this.

It is the opinion of the S.E.P.M. delegate to this meeting that the decisions made at Montreal were most salutary in making it plain that nomenclature of fossil pollen and spores is governed by the botanical rules, based on typification and priority, whereever formal names are used. Any tendency toward anarchy that may have existed has been reversed. This does not mean that fossil pollen must have formal names, of course; classification by symbols or informal terms is often preferable, though it has no formal status.

13. *SEPM President's Report (Samuel P. Ellison, Jr.)*—Based on the Secretary-Treasurer's report, the financial condition of the Society remains good in the face of rising printing and operating costs. Increased printing costs of the two journals and increases in expenses account for the decline of the General Fund but all of the special publications are now operating at a profit except the *Journal of Sedimentary Petrology* Index. The splendid sale of the special publications accounts for the improvement in the status of the Publications Fund.

Our very energetic membership committee under the chairmanship of John P. Brand has brought a total of 153 new members and associates into the Society. After drops due to non-payment of dues, the Society had a total net gain of 74 (5% gain) in 1959 as compared to a gain of 43 in 1958. I recommend the continuation of an active membership committee to not only increase the new memberships but also to encourage members in arrears to stay active.

The research committee under the chairmanship of Arthur C. Munyan organized a symposium on "Paleontological and Mineralogical Aspects of Polar Wandering and Continental Drift" for presentation at Atlantic City. The committee also selected the recipients of honorary membership and best paper awards for the journals. The com-

mittee under the chairmanship of Robert Ginsburg are planning a symposium on "Oceanography" for the Denver meeting next year.

The editors of our journals reported increased pages for both journals and an increased back-log of unpublished manuscripts on hand. A wide variety of papers from many national origins was published in both journals. A pressing need still exists for further expansion of our volumes. However, the council by necessity has adopted a 1960–61 budget that does not permit expansion of the journals.

The Council has approved the reprinting of the special publication "Regional Aspects of Carbonate Deposition." The Barker manuscript on the revision of the "Foraminifera of the Challenger Expedition" complete with plates is expected to be off the press in the summer of 1960. An Index to the Journal of Paleontology is also in press as a special publication.

The membership voted overwhelmingly to change the bylaws so that by April, 1961, the Council will be increased by two councilors. This was to increase the pool of members eligible for the presidency. The membership also advised the Council by a referendum vote that it desired to maintain the two slate method of election of officers.

The activities of the three organized sections, Gulf Coast Section, Permian Basin Section, and Pacific Section are on the increase. Field trips, regional meetings, student awards, and publications are on the programs of each section. I had the pleasure of visiting the meetings of two of the sections during the past year and I was impressed with the vigorous activity.

At its meeting of April 24, 1960, the Council of the Society gave careful consideration to the American Geological Institute reorganization proposals. The Council passed unanimously a resolution supporting these proposals in principle. Decision to raise the Society's dues for support of the American Geological Institute will, of course be made by a vote of the membership at large.

I wish to extend my sincerest gratitude to the many members of the Society who have served as officers, editors, representatives, committee chairmen and committee members during my term of office. Further, our Society is deeply indebted to the capable work performed by the Tulsa headquarters staff.

After the president's report, the meeting was turned over to the Incoming President, William M. Furnish, who called on Carl C. Branson to present the "Resolutions of Thanks."

The Resolutions Committee, composed of Carl C. Branson (Chairman), Bernhard Kummel, and E. C. Dapples, presents the following "Resolutions of Thanks."

"BE IT RESOLVED THAT in behalf of the Society, we extend an expression of our sincere thanks to the following:

TO WILLIAM J. PLUMLEY, technical program chairman, for the assembling of and the efficient handling of the technical program;

TO RICHARD S. BOARDMAN, S.E.P.M. vice-chairman, for his capable management of the many details involved in having a successful convention;

TO ARTHUR C. MUNYAN, chairman of the Research Committee, for securing papers and preparing the Research Symposium, "The Paleontological and Mineralogical Evidence for Polar Wandering and Continental Drift";

TO PAUL TASCH and ALBERT L. KIDWELL for arranging the program on paleontology and mineralogy;

TO HARRY S. LADD, general chairman, GEORGE V. COHEE, general vice-chairman, FRANCIS J. PETTIJOHN, A.A.P.G. program chairman, and to the chairmen and members of all the convention committees for their efforts in behalf of the meeting;

TO THE EXECUTIVE COMMITTEE of the A.A.P.G. for appropriating $2,000.00 as office rent for the Society Headquarters at Tulsa;

TO OUR EDITORS, M. L. THOMPSON, CHARLES W. COLLINSON, and JACK L. HOUGH for maintaining the high quality of our Journals;

TO ROBERT H. DOTT for his sound and discerning judgment in the business affairs of our Society;

AND TO THE CHALFONTE-HADDON HALL for providing excellent convention headquarters facilities."

It was moved, seconded, and carried that the meeting be adjourned.

CONSTITUTION AND BY-LAWS

(AMENDED, 1959)

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

A DIVISION OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

CONSTITUTION

ARTICLE I. NAME

The Society shall be known as the Society of Economic Paleontologists and Mineralogists.

ARTICLE II. OBJECT

The object of the Society shall be to promote the science of stratigraphy through research in paleontology and sedimentary petrology, especially as these relate to development of knowledge of the geology of petroleum.

ARTICLE III. MEMBERSHIP

1. The Society shall be composed of active members, associate members, honorary members, correspondents, and patrons.

2. Active members shall be persons engaged in paleontologic, petrographic, or stratigraphic studies as applied to the geology of petroleum and who have been duly elected active members, juniors, or associates in The American Association of Petroleum Geologists.

Active and honorary members only shall be known as members.

3. Associate members shall be known as associates. Any person engaged in paleontologic, petrologic, or stratigraphic studies that have application to the geology of petroleum is eligible for associate membership. Associates shall enjoy all the privileges of membership in the Society, save that they shall not hold office, sign applications for membership, or vote.

4. Honorary members shall be persons of distinguished achievement whose contributions to paleontology, petrology, and stratigraphy have an application to the geology of petroleum.

5. Correspondents shall be persons not resident in North America who have made distinctive contributions to paleontology, petrology, and stratigraphy that have application to the geology of petroleum.

6. Patrons shall be persons who have bestowed important favors on the Society.

ARTICLE IV. OFFICERS

1. Executive authority of the Society is vested in a council consisting of eight members, duly elected officers, as follows: president, vice-president, secretary-treasurer, the past-president, two councilors, and the editor of each of the two Journals. The chairman and the vice-chairman of the Research Committee and the presidents of Regional Sections shall be non-voting members of the council.

2. The president shall discharge the usual duties of a presiding officer at all meetings of the Society and council.

3. The vice-president shall assume the duties of the president in case of his absence.

In the event of the absence from the meetings of both president and vice-president, the duties of presiding officer shall fall upon one of the other members of the council in the following order: past-president, secretary-treasurer.

4. The secretary-treasurer shall keep records of the proceedings of the Society, and a complete list of the membership. He shall attend to the preparation and mailing of notices and other materials required in the business of the Society. The secretary-treasurer shall have custody of all funds of the Society, and shall keep a detailed account of receipts and disbursements.

5. The councilors shall participate in the deliberations of the council and perform specific duties with respect to membership, publications, and other affairs of the Society as shall be assigned to each by the president.

6. The council shall consider all nominations for membership and pass on the qualifications of the applicants; may elect honorary members, correspondents, and patrons; shall have control and management of the affairs and funds of the Society; shall determine the manner of publication and pass on the material presented for publication; and

shall designate the place of the annual meeting. In the event of a tie vote among the voting council, the president, vice-president, and secretary-treasurer's votes shall prevail. The council is empowered to establish a business headquarters for the Society and to employ such persons as are needed to conduct the business of the Society.

7. Elections shall be held annually to select a president, vice-president, secretary-treasurer, two councilors, and the editors.

ARTICLE V. MEETINGS

1. The Society shall hold at least one stated meeting a year, which shall be designated as the annual meeting. The time and place of the annual meeting shall be designated by the council, but in general, it shall be held in connection with the annual meeting of The American Association of Petroleum Geologists.

2. The annual meeting shall be devoted to the reading and discussion of scientific papers, to the transaction of Society business, and other appropriate functions.

3. The program for the annual meeting shall be arranged by the council, or under its direction.

ARTICLE VI. SECTIONS

Local sections of the Society may be established according to provisions of the by-laws.

ARTICLE VII. AMENDMENTS

The constitution may be amended by a two-thirds vote of returned mail ballots received by the secretary-treasurer sixty days after proposal of amendments with provision for vote is mailed to the membership; provided that the proposed amendment has been signed by at least twenty members, and provided further that the proposed amendment must first have the approval of the council and the executive committee of The American Association of Petroleum Geologists.

BY-LAWS

ARTICLE I. DUES

1. The fiscal year of the Society shall correspond with the calendar year.

2. The annual dues of members and associates of the Society who desire only the *Journal of Paleontology* shall be ten dollars ($10.00). The annual dues of members and associates who desire only the *Journal of Sedimentary Petrology* shall be seven dollars ($7.00). Members and associates may receive both Journals by the payment of seventeen dollars ($17.00). Members of the Society who are also members of the Paleontological Society and receive the *Journal of Paleontology* through the latter Society, may retain membership in the Society of Economic Paleontologists and Mineralogists by the payment of two dollars ($2.00) per year dues. The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member and associate before September 1 of each year, stating the amount of annual dues and the penalty and conditions for default of payment. Members and associates who shall fail to pay their annual dues by January 1 shall not receive further copies of either Journal, nor shall they be privileged to buy Society publications at special discounts made to the membership, until such arrears are met.

3. The council may from time to time elect as honorary members, correspondents, and patrons, candidates who have been nominated by a majority vote of the research committee. A vote of four members of the council shall be required for election. Honorary members, correspondents, and patrons shall not be required to pay annual dues.

ARTICLE II. DUTIES AND PRIVILEGES OF MEMBERS

1. Members and associate members dropped for non-payment of dues may apply to the council for reinstatement, and, provided settlement is made of any outstanding indebtedness for publications and other charges approved by the council, may be reinstated by vote of four members of the council.

2. Members shall be eligible to receive publications of the Society at special subscription rates as authorized by the council or as provided in these by-laws.

3. The council is authorized to transmit without charge such publications as it may

direct to honorary members, correspondents, and patrons.

4. Only active and honorary members shall have the right to vote in electing officers and in transacting the business of the Society.

ARTICLE III. OFFICERS

1. Nominations for officers shall be made in the following manner. Prior to September 1 of each year, the president shall designate a nominating committee to consist of not less than five members, none of whom shall be members of the council, instructing this committee to submit two nominations for president, vice-president, and secretary-treasurer, four nominations for the offices of councilor, and nominations for editors of the two Journals, these nominations to be in the secretary's hands before September 15. If desired, this committee may nominate two slates of candidates for editor of one or both of the Journals.

2. Ballots containing the nominations for officers, alphabetically arranged under each office, shall be prepared by the secretary-treasurer and mailed to each member of the Society on or before October 1. Neither the ballot nor the enclosing envelope need contain the name of the voting member, but an outer envelope that contains the sealed ballot must bear the name of the voting member. The returned ballots received by the secretary-treasurer on or before December 1 shall be counted by him, and if requested, shall be submitted to recount by the council. A plurality of the votes received for any office constitutes election.

3. If, after his election by the regular ballot, the president shall not be able to discharge the duties of his office, because of death or resignation, the duly elected vice-president shall then assume the duties and title of president with all of the authority vested in him by the Constitution. In the event the vice-president shall not be able to assume said duties, then the succession shall be in the following order: past-president, secretary-treasurer. If none of the above mentioned members of the council shall be able to assume the office of the president, then a special election shall be held in which at least two qualified members, nominated by the council, shall be voted upon by the membership by means of a special mailed ballot. Any vacancies in the normally constituted council caused by such succession or for any other reason may be filled with a temporary appointment by the council.

4. Nominees for the office of president shall be active members in good standing who shall have served, or may be serving concurrently at the time of nomination, as vice-president, secretary-treasurer, councilor, chairman of the Research Committee, or editor of one of the Society's official publications.

5. The vice-president shall be the officer of the council responsible for arrangements for the annual meeting, including selection of program chairmen, and shall keep in close contact with the Research Committee and others concerning technical papers and symposia to be presented.

ARTICLE IV. PUBLICATIONS

1. There shall be two editors, one for the *Journal of Paleontology* and one for the *Journal of Sedimentary Petrology*. The editors shall be in charge of editorial business of their respective Journals. Each shall submit an annual report of such business, shall have authority to solicit papers and material for such Journals, and may appoint associate or co-editors.

2. The *Journal of Paleontology* and the *Journal of Sedimentary Petrology* are designated as official publications of the Society. The council is not authorized to initiate and publish other periodicals.

3. A publication fund may be established consisting of an assignment of a portion of dues as designated by the council, and such donations as are specifically made for that purpose. The council is authorized to provide special publications from this fund as may be deemed desirable, and to fix terms for sale or other distribution of these publications.

ARTICLE V. FINANCIAL METHODS

1. No financial obligations shall be contracted without express sanction of the Society or council, but all ordinary incidental running expenses have sanction without special action.

2. Statements of accounts charged to the Society, other than miscellaneous running

expenses, shall be approved by the president before the secretary-treasurer pays the amount out of funds of the Society not otherwise appropriated, and the receipted bill shall be held as the secretary-treasurer's voucher.

3. The secretary-treasurer shall have charge of the financial affairs of the Society and shall annually submit reports as secretary-treasurer covering the fiscal year. He shall receive all funds of the Society, and, under the direction of the council, shall disburse all funds of the Society. He shall cause an audit to be prepared annually by a public accountant at the expense of the Society. He shall give a bond, and shall cause to be bonded all employees to whom authority may be delegated to handle Society funds. The amounts of such bonds shall be set by the council and the expense shall be borne by the Society. The funds of the Society shall be disbursed by check as authorized by the council.

ARTICLE VI. BUSINESS REPRESENTATIVES

The president and the secretary-treasurer of the Society shall act as business representatives of the Society in the business committee of The American Association of Petroleum Geologists. These representatives shall conduct such business with the executive committee of the Association as is of mutual interest to the Society and the Association in the interims between the annual meetings of the Society and the Association. Approval of the action of these representatives on the part of the Society during any year is reserved to the council in session at the annual meeting at the close of that year. Questions remaining unsettled between the representatives of the Society and the executive committee of the Association shall be considered in a joint meeting of the council of the Society or its authorized representatives and the executive committee of the Association at the annual meeting of the Association at the close of the interim period during which such questions have arisen.

ARTICLE VII. SECTIONS

1. The establishment of local sections of the Society may be authorized by unanimous vote of the council approving a petition for such establishment signed by ten members of the Society. Such local sections may elect officers, conduct meetings, and engage in other scientific activities.

2. The council is authorized and directed to withdraw the charter of any established local section if there is evidence that it has become inactive.

ARTICLE VIII. DIRECTORS OF AMERICAN GEOLOGICAL INSTITUTE

1. The president and the past-president shall be directors of the American Geological Institute, the past-president being the senior director. They shall represent the Society on said Institute. The term of office as directors shall begin at the fall meeting of the American Geological Institute following assumption of their office and shall terminate two years later; provided that this provision in no way extends their terms of office as members of the council of the Society.

2. In the event of a vacancy by resignation, death, or other causes among the two directors who represent the Society on said Institute, the president of the Society shall nominate a director from the ranks of active members of the Society, and this director shall complete the unexpired term.

ARTICLE IX. REPRESENTATIVE ON NATIONAL RESEARCH COUNCIL

At the expiration of each three-year term, the president shall appoint a representative on the National Research Council to serve for a term of three years.

ARTICLE X. RESEARCH COMMITTEE

1. The objectives and duties of the Research Committee shall be to foster and encourage research; to advise the Society and council on research activities which may concern the Society, or which may be recommended or initiated under its sponsorship; to develop a symposium for the annual meeting if so requested; to select recipients for Best Paper Awards each year for each Journal; to nominate candidates for honorary members, correspondents, and patrons; and to deal with any other matters referred to it from time to time by the president or the council.

2. The activities of the Committee shall

be directed by a chairman and a vice-chairman, to be appointed by the president, with the approval of the council, from the active members of the Committee. The term of the appointment of the chairman shall be one year. The vice-chairman will normally succeed the chairman the following year. In the event either of these offices is vacated for any reason, the council shall appoint a qualified replacement for the unexpired term.

3. Membership of the Committee shall be appointed by the president from members and associates of the Society. The Committee shall consist of fourteen members, but this total may be changed at the discretion of the council. Two committee members, preferably one paleontologist and one mineralogist, shall be chosen from each of several geographic regions to be selected by the council. In addition, advisory members may be appointed from foreign areas. The terms of appointment of members and advisory members shall be for three years. Appointments shall be staggered, with the junior member from any region serving at least one year with the senior member from that region. If vacancies develop on the Committee the president shall make suitable appointments for the unexpired term.

ARTICLE XI. PUBLICATIONS COMMITTEE

1. The membership of this committee shall consist of five members, including a chairman, three other members, and the chairman of the Research Committee as an ex-officio member. The tenure of office of the chairman and members shall be two years. Membership of the committee shall be appointed by the president from members and associates of the Society.

2. The duties of the Publications Committee shall be to recommend to the council manuscripts or symposia which merit consideration as S.E.P.M. special publications. The Publications Committee shall further recommend type of reproduction, number of copies, and cost figures of manuscripts or symposia.

3. Upon approval of the council, this committee, with the appropriate Society editor or editors, shall edit (or have edited), and publish these manuscripts or symposia.

4. The activities of this committee will include recommending to the council suggestions for improving the quality of our Society *Journals* consistent with the budgeted monies allotted for publication.

ARTICLE XII. AMENDMENTS

The by-laws may be amended at any annual business meeting by two-thirds vote of the members present, or by mail ballot sent to the members, in which case two-thirds of the returned ballots received in sixty days after mailing must approve the amendment in order to make it effective. Any proposed changes to the by-laws must first have the approval of the council.

NOMINEES FOR S.E.P.M. PRESIDENT, 1961–1962

LAURENCE L. SLOSS

Professor of Geology, Northwestern University, Evanston, Illinois
Born, August 26, 1913, Mountain View, California

Academic Training

Stanford University, B.A., '34
University of Chicago, Ph.D., '37

Experience

1937–46	Montana School of Mines (instructor, assistant professor), and Montana Bureau of Mines and Geology (geologist)
1947–	Northwestern University (assistant, associate, professor)
1942–50	(Summers) Carter Oil Co., Phillips Petr. Co., U.S.G.S. (structure and stratigraphy, Rocky Mountain Area)

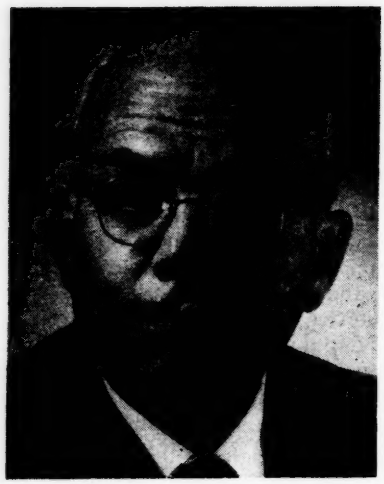
Publications.—Stratigraphy and sedimentary petrology

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
Paleontological Society, member
American Geophysical Union, member
American Association for the Advancement of Science, fellow

S.E.P.M. Activity (Member, '48)

1950	Program Chairman
1954	Nominating Committee
1955–57	Research Committee Member
1959	Co-Chairman Research Committee Symposium
1960–61	Vice-President



CURT TEICHERT

Geologist, U. S. Geological Survey, Denver, Colorado
Born, May 8, 1905, Königsberg i. Pr., Germany

Academic Training

Albertus University (Königsberg), Ph.D., '28
University of Western Australia, D.Sc., '44

Experience

1927–29	University of Freiburg (assistant)
1930	U. S. National Museum, N. Y. Museum (Rockefeller fellow)
1931–32	Danish Expedition to Greenland (geologist)
1933–37	University of Copenhagen (paleontologist)
1937–45	University of Western Australia (research lecturer)
1946–47	Mines Department of Victoria, Australia (asst. chief geologist)
1947–53	University of Melbourne (senior lecturer)
1953–54	New Mexico Institute of Technology (professor)
1954–	U. S. G. S. (geologist)

Publications.—Stratigraphy, paleontology (esp. cephalopods), coral reefs

Professional Affiliations

Geological Society of America, fellow
American Association of Petroleum Geologists, member
Paleontological Society, member (correspondent, 1951–53)
Paleontological Research Institution
Geochemical Society

S.E.P.M. Activity (Associate, '52; Member, '56)

1954–57	Research Committee (Chairman, 1956–57)

NOMINEES FOR S.E.P.M. VICE-PRESIDENT, 1961–1962

KENNETH E. LOHMAN

Geologist, U. S. Geological Survey, Washington, D. C.
Born, September 11, 1897, Los Angeles, California

Academic Training

California Institute of Technology, B.S., '29; M.S., '31; Ph.D., '57

Experience

1924–26	Certified Laboratory Products (chemist)
1926–31	(Part time) Certified Laboratory Products (chemist)
1931–	U. S. Geological Survey (geologist)

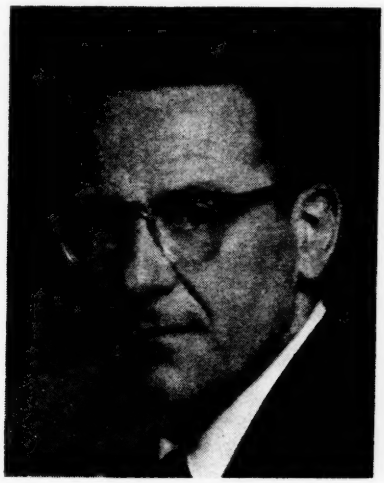
Publications.—Diatoms, stratigraphy

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
American Association for the Advancement of Science, fellow
American Geophysical Union, member

S.E.P.M. Activity (Member, '60)

1960	Chairman, Technical Services Committee



FRANKLYN B. VAN HOUTEN

Professor of Geology, Princeton University, Princeton, New Jersey
Born, July 14, 1914, New York City

Academic Training

Rutgers University, B.S., '36
Princeton University, Ph.D., '41

Experience

1939–42	Williams College (teaching and research)
1946–	Princeton University (professor)

Publications.—Sedimentation and vertebrate paleontology

Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, fellow
Sigma Xi

S.E.P.M. Activity (Member, '49)

1954–57	Research Committee

NOMINEES FOR S.E.P.M. SECRETARY-TREASURER, 1961–1962

LAWRENCE C. BONHAM

Research Geologist, California Research Corporation, La Habra, California
Born, June 9, 1920, Springfield, Missouri

Academic Training

Drury College, B.S., '42
Washington University, M.S., '48; Ph.D., '50

Experience

1942–44	U. S. Coast and Geodetic Survey (photogrammetric engineer)
1944–46	U. S. Army Air Force (photogrammetrist)
1946	Missouri Geological Survey (geologist)
1948, 49	(Summers) Jersey Production Research Co. (geological research)
1950–	California Research Corporation (geological research)

Publications.—Organic geochemistry, structural petrology

Professional Affiliations

American Association of Petroleum Geologists, member

S.E.P.M. Activity (Member, '59)

LLOYD C. PRAY

Research Geologist, The Ohio Oil Company, Littleton, Colorado
Born, June 25, 1919, Chicago, Illinois

Academic Training

Carleton College, B.A., '41
California Institute of Technology, M.S., '43; Ph.D., '52

Experience

1942	Magnolia Petroleum Co. (subsurface geology)
1943–44	U. S. Geological Survey (pegmatite investigations)
1944–46	U. S. Navy (hydrographic surveys)
1946–56	U. S. Geological Survey (rare earth deposits)—Part time
1950–56	California Institute of Technology (instructor, assistant professor)
1956–	The Ohio Oil Co. (geological research)

Publications.—Stratigraphy, structural geology, petrology

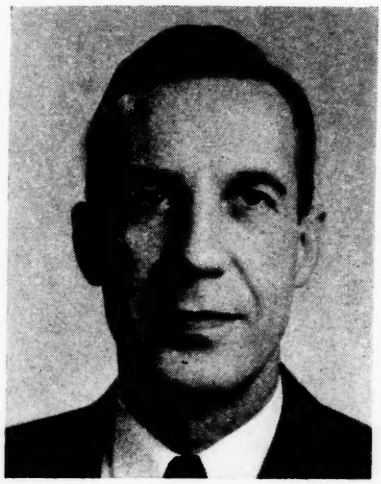
Professional Affiliations

American Association of Petroleum Geologists, member
American Institute of Mining, Metallurgical and Petroleum Engineers, member
Geological Society of America, fellow

S.E.P.M. Activity (Member, '55)

1959	Leader, Field Conference, Permian Basin Section, S.E.P.M.

NOMINEES FOR S.E.P.M. COUNCILOR (PALEONTOLOGY), 1961–1962



LYMAN D. TOULMIN

Professor of Geology, Florida State University, Tallahassee, Florida
Born, July 4, 1904, Mobile, Alabama

Academic Training

University of Alabama, B.A., '26; M.S., '34
Princeton University, Ph.D., '40

Experience

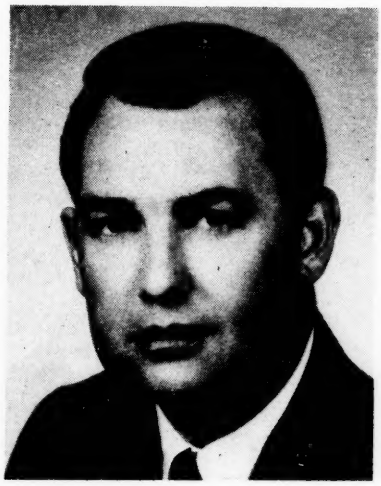
1938–42	Texas A. & M. College (instructor, assistant professor)
1942–45	Geological Survey of Alabama (geologist)
1945–48	Birmingham Southern College (associate professor)
1953–54	Louisiana State University (visiting professor)
1948–	Florida State University (associate professor, professor)

Publications.—Paleontology and stratigraphy

Professional Affiliations

American Association of Petroleum Geologists, member
Paleontological Society, member
Geological Society of America, fellow
American Association for the Advancement of Science, fellow
Sigma Xi

S.E.P.M. Activity (Member, '54)



GARNER L. WILDE

Paleontologist, Humble Oil & Refining Company, Midland, Texas
Born, September 29, 1926, Spring Creek, Texas

Academic Training

Texas Christian University, B.A., '50; M.A., '52

Experience

1950–52	Texaco, Inc. (paleontological assistant)
1952–	Humble Oil & Refining Co. (paleontologist)

Publications.—Paleontological studies on fusulinids

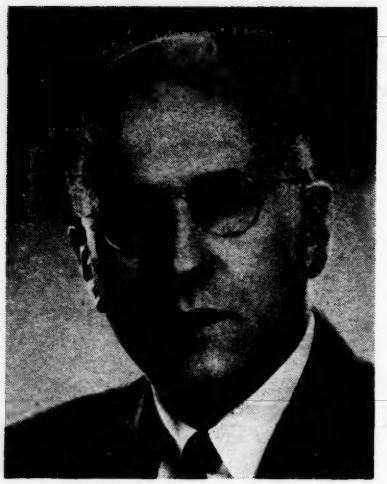
Professional Affiliations

American Association of Petroleum Geologists, member
Geological Society of America, member

S.E.P.M. Activity (Member, '53)

1955	Chairman, Steering Committee, to organize Permian Basin Section, S.E.P.M.
1960–61	President, Permian Basin Section (Non-voting member of the Council)

NOMINEES FOR S.E.P.M. COUNCILOR (MINERALOGY), 1961–1962



WILLIAM C. GUSSOW

Staff Geologist, Union Oil Company of California, Calgary, Alberta, Canada
Born, April 25, 1908, London, England

Academic Training

Queen's University (Kingston, Ontario), B.S., '33; M.S., '35
Massachusetts Institute of Technology, Ph.D., '38

Experience

1945–52 Shell Oil Company (chief geologist, exploration manager)
1953–55 Consulting geologist and engineer
1956– Union Oil Company of California (staff geologist)

Publications.—Differential entrapment and migration of oil and gas, stratigraphy, structural geology

Professional Affiliations

Royal Society of Canada, fellow
Geological Society of America, fellow
Geological Association of Canada, fellow
American Association of Petroleum Geologists, member
Society of Economic Geologists, member
American Geophysical Union, member
Canadian Institute Mining and Metallurgy, member

S.E.P.M. Activity (Member, '56)

1960 Co-Chairman Research Committee Symposium

ALBERT L. KIDWELL

Research Geologist, Jersey Production Research Company, Tulsa, Oklahoma
Born, January 1, 1919, Auxvasse, Missouri

Academic Training

Missouri School of Mines, B.S., '40
Washington University, M.S., '42
University of Chicago, Ph.D., '49

Experience

1942–44 U. S. Coast and Geodetic Survey (construction of maps)
1944–47 Missouri Geological Survey (geologic mapping and economic geology)
1950– Jersey Production Research Company (research)

Publications.—Recent sediments and occurrence of oil

Professional Affiliations

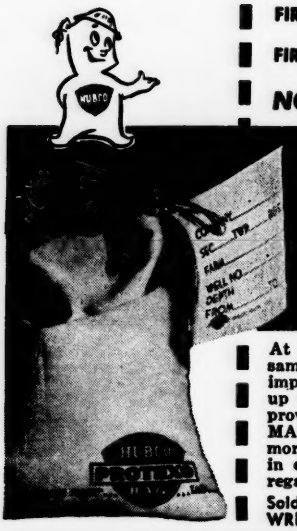
American Association of Petroleum Geologists, member
Geological Society of America, member
Mineralogical Society of America, member
Sigma Xi

S.E.P.M. Activity (Member, '59)

1960 Organized program on Mineralogy

NEW OFFICERS, PERMIAN BASIN SECTION, S.E.P.M.

President: GARNER L. WILDE, Midland, Texas.
First Vice President: BERNOLD M. HANSON, Midland, Texas.
Second Vice President: GREGORY L. TURNER, Fort Worth, Texas.
Secretary: CYRIL J. PERUSEK, Midland, Texas.
Treasurer: RICHARD D. JONS, Midland, Texas.



FIRST... with the handy-pack dispenser — stops waste!

FIRST... with geologist-designed bag — strong, sift-proof!

FIRST... with "Magic-Mark" tag—holds pencil markings!

NOW, FIRST WITH THE NEW

GOLDEN
MAGIC MARK
TAG
EASIER TO READ
easier to recognize

At an approximate cost of $2.00 each sample to collect and process, losses of important data due to inferior bags adds up to a big expense. Now, with the improved readability of the new "GOLDEN MAGIC MARK TAG", HUBCO bags, more than ever before prove their worth in dollar savings. Data is always legible regardless of mud and moisture!

Sold by oil field supply jobbers, dealers. WRITE us for FREE sample and price list. JP

HUTCHINSON BAG CORP. P O Box 868, Hutchinson, Kansas

TRANSLATORS. Proven ability to translate technical material into fluent English essential. Attractive full time or free-lance arrangement. All languages of interest, particularly Russian & Japanese. Send resume to: A.T.S., Inc., Drawer 271, East Orange, N.J.

McLEAN PALEONTOLOGICAL LABORATORY

Card catalogues of fossils available by subscription, created on contract or by mutual agreement. Compilation and research facilities by contract. Training program for micropaleontologists offered.

James D. McLean, Jr., Box 916, Alexandria, Virginia, U.S.A.

★ *Ex-British Government* ★

GEOLOGICAL INSTRUMENTS, ETC.

SURVEYING RANGEFINDERS

Coincidence type. Base 80 cm. Range 250-10,000 yards. Good serviceable condition. Freight charges at cost. Short or tall tripod can be supplied as an extra.

$34.50

INDIAN CLINOMETERS

Base 9½ in. Ministry release at fraction of cost. New and unused.

$10.50 *Post and packing $1.75.*
With Leather Case

SIGHTING PLANE TABLE ALIDADES

An extremely well-made instrument constructed of Phosphor Bronze fitted with sighting vanes parallel rule attachment. Length 18 in. Net weight 2½ lb. In polished wood container, all in new condition. Fraction of cost.

$5 *Post and packing $1.75*

BOX SEXTANTS

Of special interest to the Land Surveyor, this compact instrument is three inches in diameter and weighs only 1 lb. Scale is divided to 130° and angles can be read by vernier to one minute of angle. Excellent condition in leather case.

$14 *Post and packing $1.75.*

ABNEY LEVELS EX.M.O.S.

The most popular of the minor instruments for measurement of vertical angles, this pocket size reflecting level is the standard type, extending by two draws to 7 inches. The silvered arc is divided 0-90 degrees elevation and depression, and vernier can be read through the adjustable magnifier to within 10 minutes. These fine instruments are complete in leather case, and are offered in new condition at approx. half price.

$10.50 *Post and packing $1*

THE NEW UTILITY

GEIGER COUNTER

Details on request

$8.25
With Tripod

Post and packing $4.50, Tripod $1.75

REFLECTING CLINOMETER

An extremely compact Clinometer measuring 2½ in. in diameter and weighing only 6 ozs. Angles of up to 45° elevation and depression can be read instantly to an accuracy of 1° or interpolated to 15 minutes. Complete in leather case. Brand new condition.

$5 *Post and packing $1*

HELIOGRAPHS

5 in. latest pattern with two spare mirrors. Double-jointed sighting rod, etc. Complete in leather case. Cost approx. $100. Brand new and perfect.

LIQUID PRISMATIC POCKET COMPASS

Service pattern Mk. III. Precision pocket instrument engraved 0-360° in one degree divisions. The mother-of-pearl dial is suspended in non-freezing liquid. Adjustable magnifying prism. Well-made hinged case of 2 in. diameter. Net weight 11 oz. Current cost approx. $40.

$11.25 *Post and packing $1.*

CHARLES FRANK Ltd.

67-75 SALTMARKET, GLASGOW, C.1. SCOTLAND

We carry a comprehensive stock of H.O.S. Contractor and Survey equipment and our catalogue includes details of Binoculars, Telescopes, Plane tables, tripods, emerald barometers, drawing instruments, etc. Instrument makers and suppliers of scientific equipment since 1907. Actual makers of pre-war pocket telescope mirrors, special purpose glass, prisms, etc. Send for illustrated catalogue.

ORDER NOW

LIMITED PRINTING

JOURNAL OF SEDIMENTARY PETROLOGY

BACK IN PRINT

Volume 19, 1949, Numbers 1-3 (Paper Bound) $4.50

Volume 21, 1951, Numbers 1-4 (Paper Bound) $6.00

(Add 2% sales tax for books to be delivered in Oklahoma)

Send Checks to:

Society of Economic Paleontologists and Mineralogists

Box 979

Tulsa 1, Oklahoma